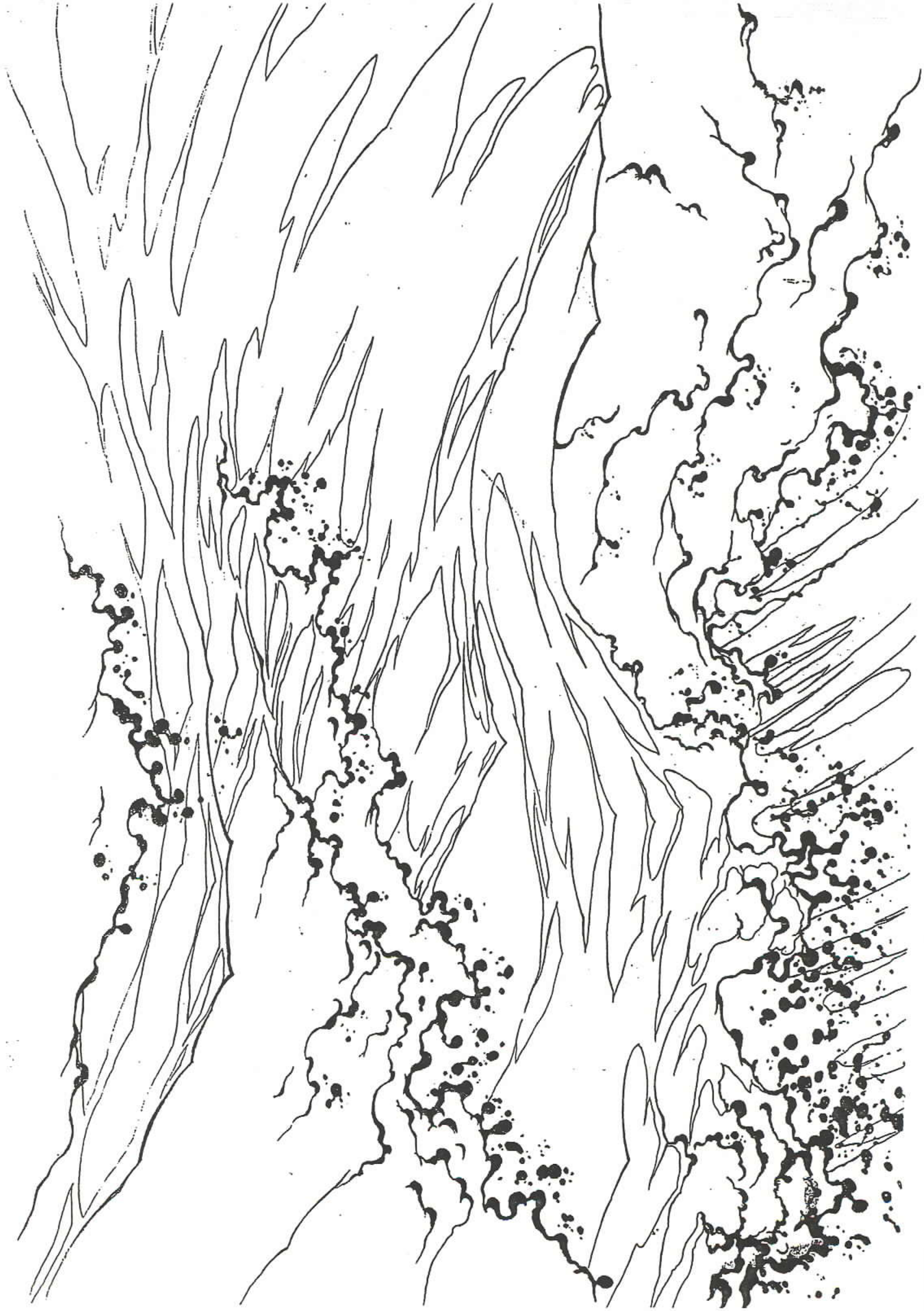


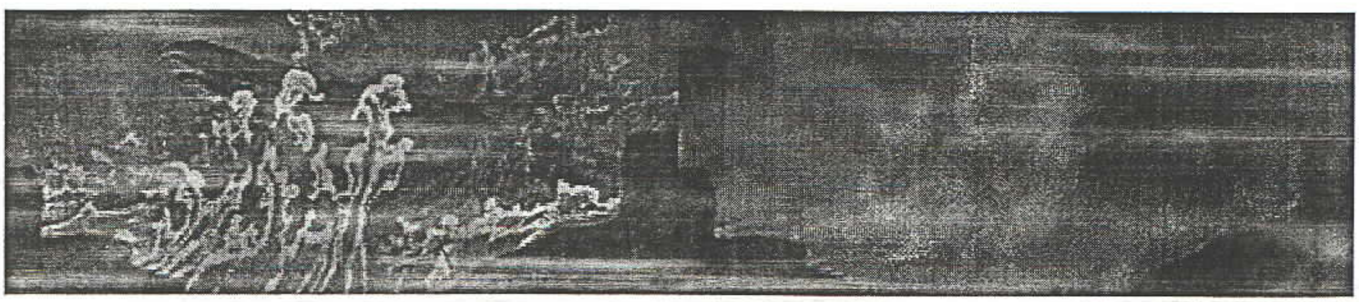
Fire and smoke
David Tidgwell

When you draw fire or smoke, you are basically drawing visible air currents. You can see the shape of the air because its filled with luminous gas or smoke particles.

The best way to start an effect you have never animated before is to first study any live action reference you can get a hold of. First study the real thing if its practical (a candle, a fireplace fire), but for violent or large effects you'll have to dig up a movie like Backdraft or Die Hard. No matter how obscenely violent an effect you're looking for, someone has probably filmed it and stuck it in a film for children.

After studying the real thing, look at animation to see how others have interpreted reality. This is always somewhat risky because there is no assurance scenes are animated well, or in the style of the film you're currently working on.

There are many different solutions to any one assignment, dependent on:
-The style of the movie
-The lighting or camera moves
-The intent of the scene (humor or drama)
-The intended role of the efx in that scene (usually the efx should be supportive and unintrusive, but is sometimes the motivator in the scene)
-How the scene will be composited. For example, if you drawings are going to be very blurred, there is no reason to add a lot of small detail (the 2 frames below are from the same drawing):



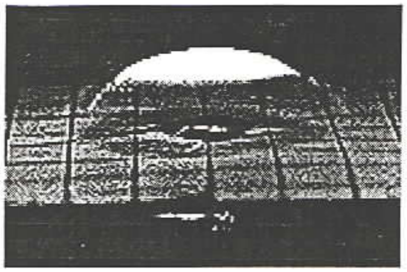
Before animating, look through the scene, plan the action, be aware of all the forces, and make a set of rules to follow involving design, motion, and timing. They can be as simple as "The fire moves up one inch per frame", or as complex as an elaborate path of action chart involving a lot of forces and a full set of thumbnails.

If you are assisting a scene, make sure you are very clear on the principles the Animator used to animate it.

Animate extremely rough, so if it doesn't work, you haven't wasted a lot of time on details.

Be prepared to throw a lot of drawings away.

Small fire

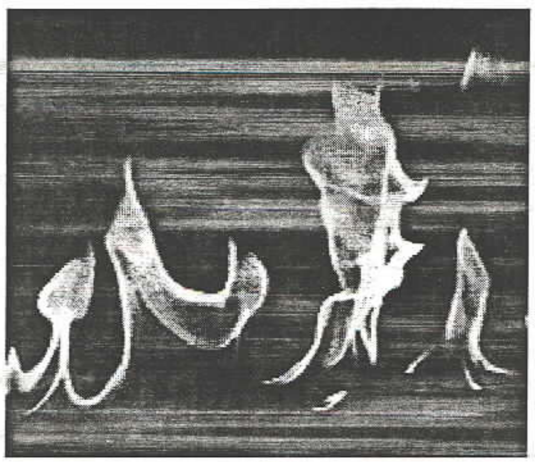


When a fire has no external forces on it, it is simply a sphere (as in the recent space shuttle experiments.)

Animating space fire would be simple: one held cel. No forces, no movement.

Add gravity, and you end up with the characteristic teardrop shape of a candle flame, caused by the heated gas rising.

Animating a candle flame in still air is almost as simple as a space flame, but it needs a little animation to stay "alive." This usually takes the form of a slight vertical flicker on ones, separated by periods of slow growing and shrinking. Some animators give it a little more life than that, moving it back and forth as if in a slight breeze.



Add wind and spreading fuel, and you can end up with a real mess. A spreading or blowing flame is more complicated to animate, but can still follow simple rules. For example, fire spreading in a pool of oil could follow these rules:

1. It spreads radially like a wave.
2. The flames at the leading edge are the largest.
3. It is rare for bits of flame to break off, and if they do, they only last one or two frames.

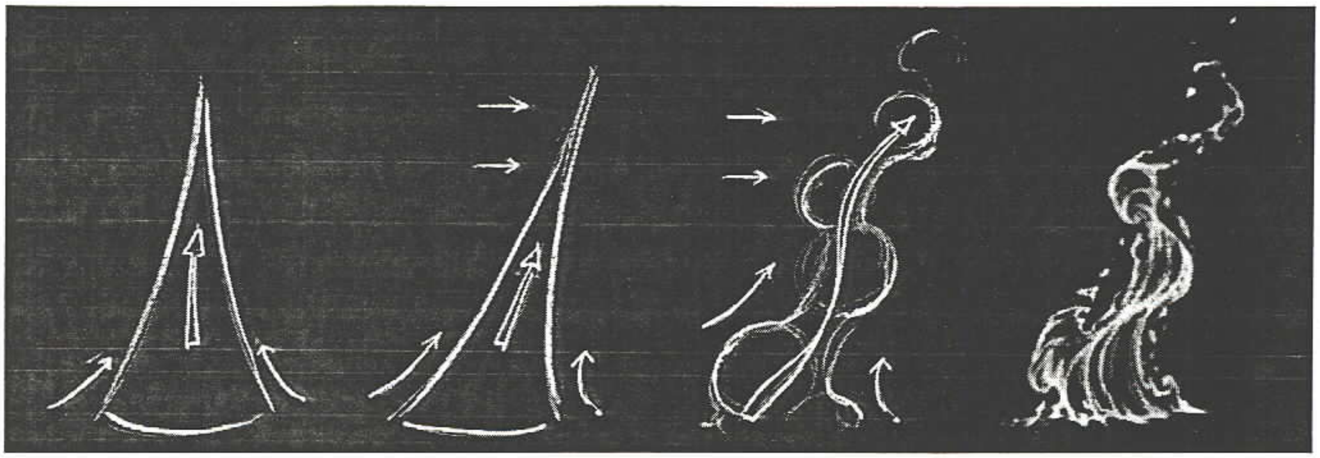
These are not holy-set-in-stone-absolute-do-it-this-way-or-die-rules, only one possible set based on observation. Just aware of what rules you are applying, whether animating or assisting a scene. It makes it easier to correct animation or inbetweens which "don't look right."

In some instances, however, you do have to abandon logic and simply let the fire dance around, relying on intuition to make it "look real." This, of course, depends on having previously internalized the movement by studying real fire.

Small flames are usually exposed with a little blur and a bright core, although there have been many variations on this theme, not all successful.

Medium sized fire

The design and animation of, say, a campfire is a bit more complicated, but fairly simple principles can be used to govern the overall motion and design.
For example, possible rules for building a campfire, starting with the simplest forces:



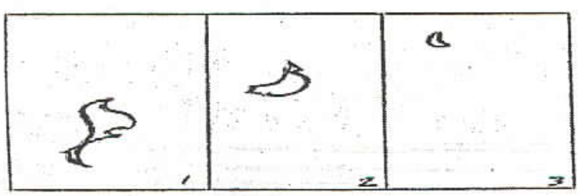
1. Hot air rises and draws air in from the bottom

2. Add a slight breeze

3. Add turbulence (alternating billows create a natural s-curve)

4. Add details

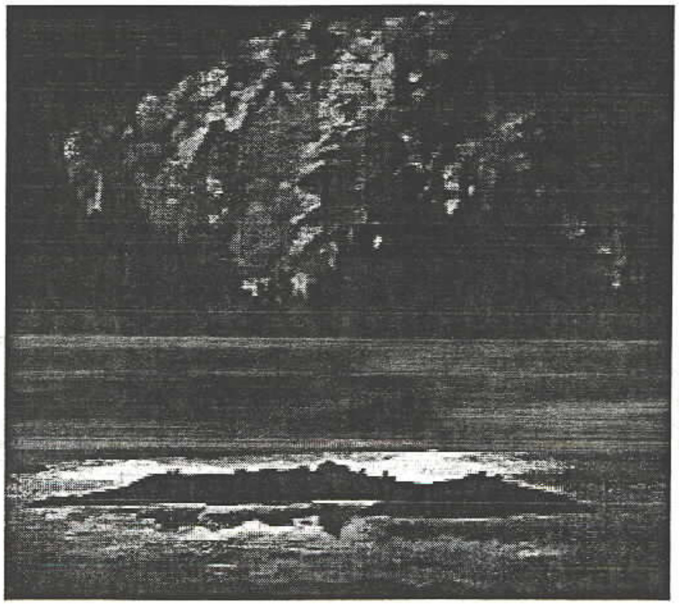
The fine details of the campfire follow their own set of rules. In practice, these details can be almost random because the larger motions are much faster than the small and your eye has a hard time seeing follow-through on the little flame details.
At the top of the fire, when a plume breaks off it continues to follow the same motion that the body of the fire follows and lasts about 4-8 frames, depending on the size of the plume breaking off.



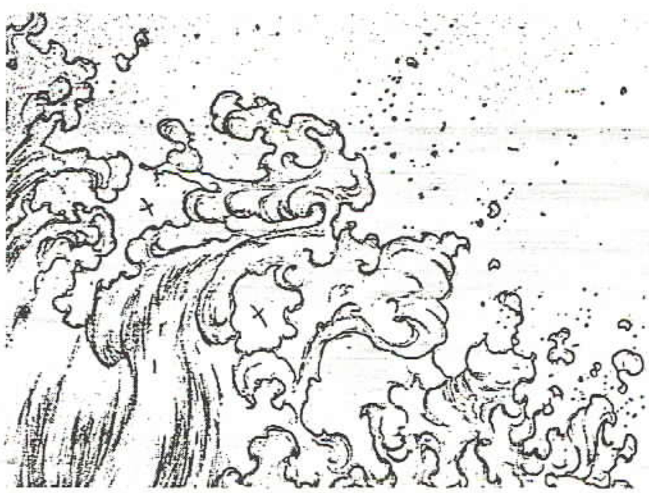
One commonly used trick to add an apparent flicker to detached bits of flame is to reverse the curve of the flame-bit every frame.

Some stylistic variations of medium-sized fire:

Big fire



Immense conflagrations (IC's) are a common sight in Disney films and as a rule, require a great deal of cheating to achieve believability. In general, since its impractical to draw a two hundred foot high wall of flames throughout a three minute sequence (four thousand frames), ripple glass or CAPS trickery is employed to give upward motion and turbulence to a rendered fire or smoke element, and foreground fire is animated normally and exposed to match the ripple-glass fire. This is a frame from the IC in Bambi.



Of course, Special Effects being the haven for psychotic masochists that it is, you will occasionally spot a scene in which every little detail is drawn. In this case, there are still a number of tricks to reduce the work to a survivable level.

One is to make an animation cycle out of the bulk of the flames and throw in a few rogue flames to distract from the cycle.

Another is to use CAPS to copy and reposition groups of flames in a clever way as to look like all original animation.

The two most important factors in making the drawings themselves look big are timing and detail.

If you have a fifty foot high flame and you decide that the flames are rising at ten feet per second, it will take five seconds (120 frames) for a detail to go from the bottom to the top of the IC.

Since you can't usually blur a large flame and make it look real, you just can't cheat the little details, especially in the silhouette. All the little flickering flamelets on the sides have to follow through and be properly timed for their scale.

This can take a long time.

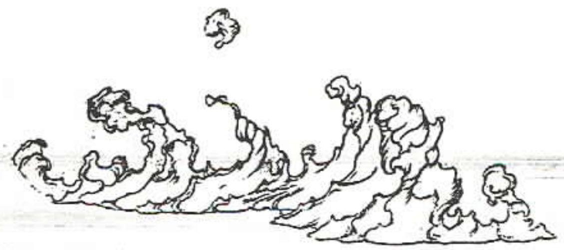
Further Fire Forms

Vortices are another common shape for fire. Very dramatic, realistic, and fun to draw.

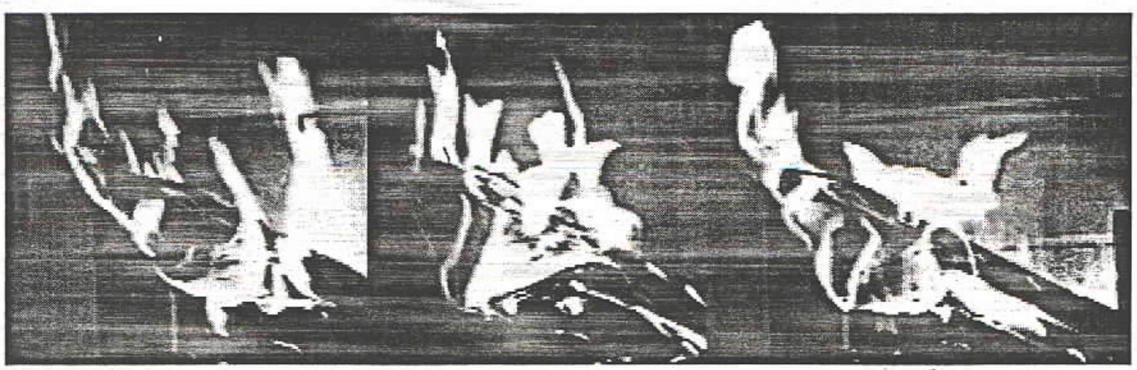
A vortex of volcanic gasses catching on fire in Fantasia:

Torch from Hunchback:

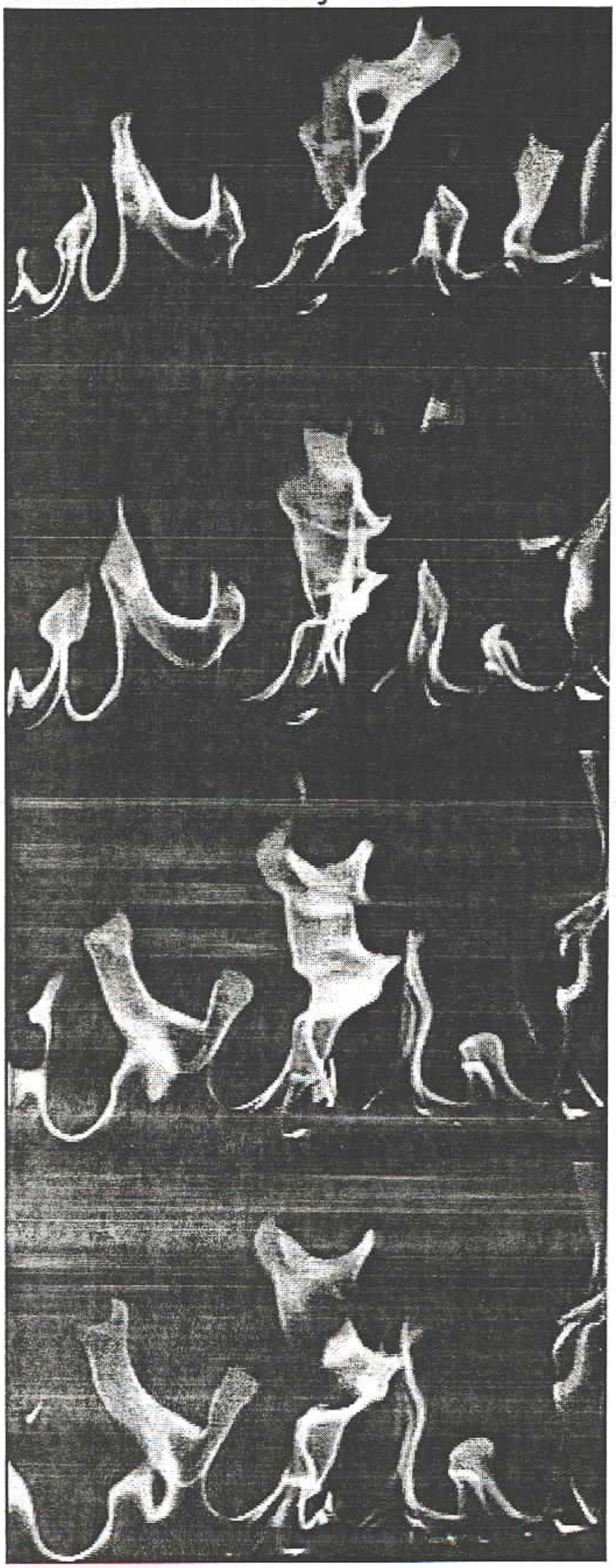
Groovy curly fire:

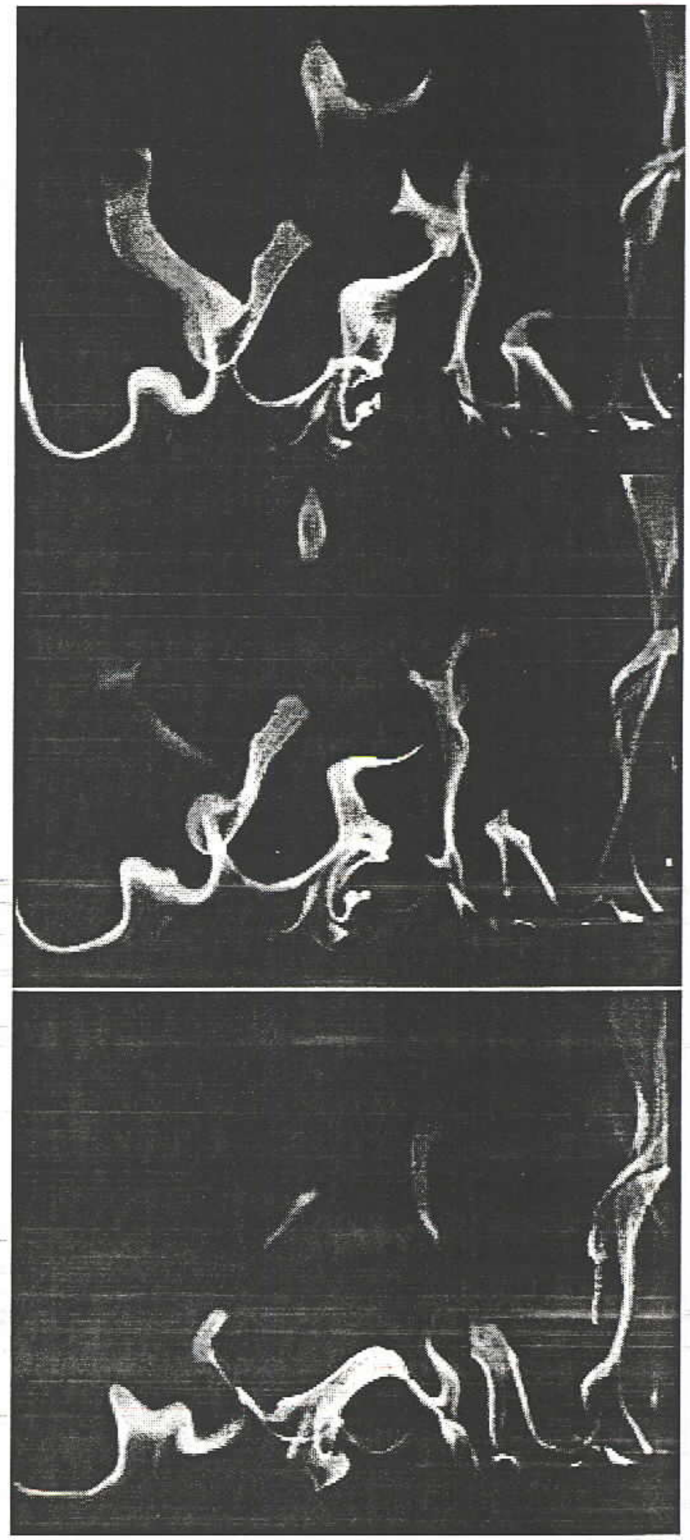


Real fire shapes are not always too pleasant:



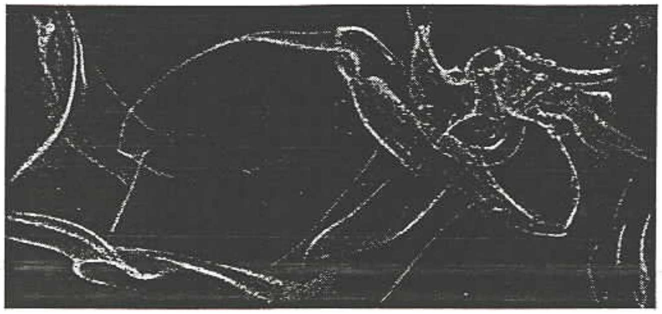
... but sometimes they are:



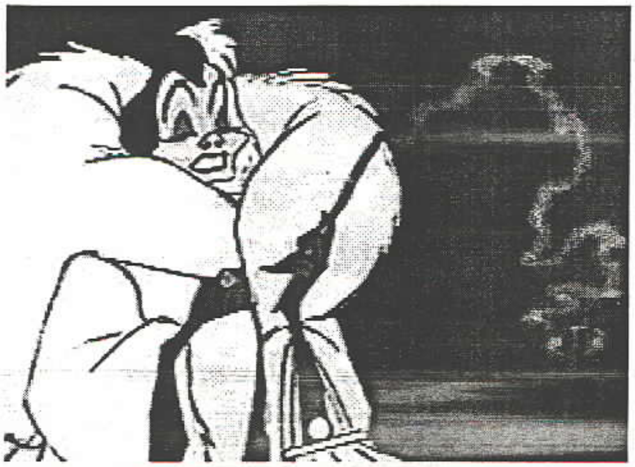


Linear smoke

There are two general forms that smoke takes, linear (incense or cigarette smoke) and billowy smoke (a campfire or an explosion.)



In reality, cigarette smoke takes on an Erte-esque, twisty, aibrushy quality as it dances lightly and nimbly to the lyrical tune of a thousand currents and eddies in the restless air. (sorry)

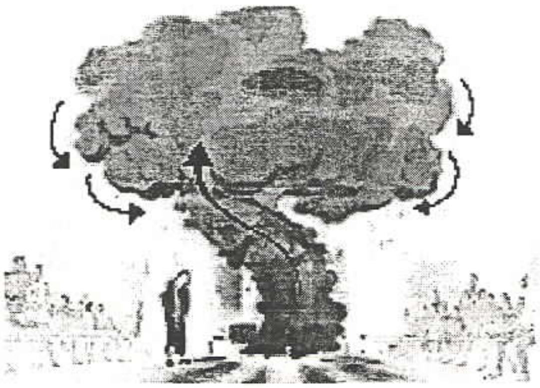


In practice, there are limits to the rendering possible within the time usually allotted for a scene. Again, there are ways around this. One is to heavily stylize the smoke and give it a strong silhouette.
Another is to have the smoke animate off shortly after it leaves the cigarette.
There are also CAPS tricks which can make smoke look rendered, although this can take very careful planning and designing.

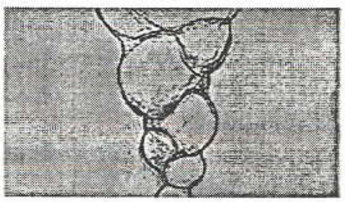
Linear smoke can be one of the more expressive (fun) types of efx to animate. It is often used for "concept" sequences, such as the opium sequence in Alice in Wonderland or the mystical smoke sequence in Pocahontas.

Its animation is not limited to being secondary action as is simple cigarette smoke, but usually includes a component of primary (motivating) movement, as if part of smoke is alive or under conscious control.

Billowy smoke

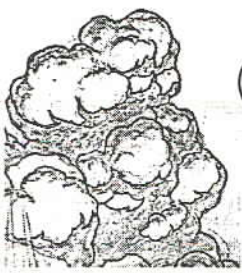


Mushroom clouds are one species of billowy smoke that illustrates the forces involved very clearly. Friction from the outside air causes the surface of the smoke to stay in place while the central rising hot air forces the center up, causing the plumes of smoke to rotate as if they were gears. Details appear to move downward, although they are actually staying in place.



Tips for constructing billowy smoke:

1. A smoke column can often be constructed with interlocking spheres. Animating the column as spheres first, then adding details can save a lot of hassle.

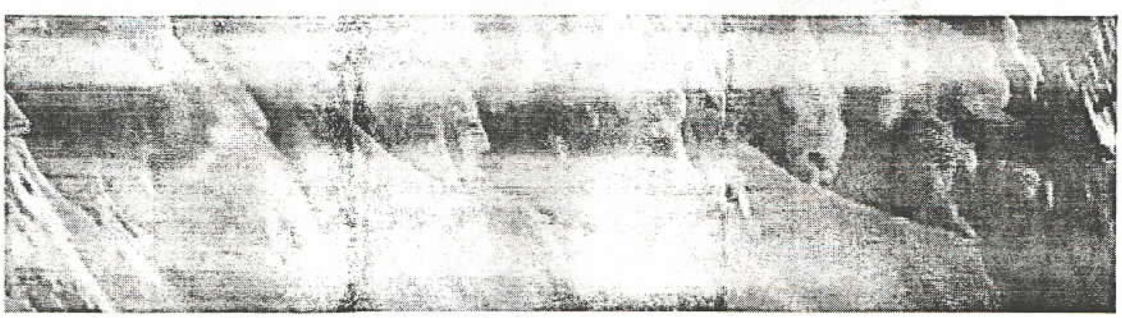


2. Use a lighted sphere to visualize the proportions between shaded and lighted areas.

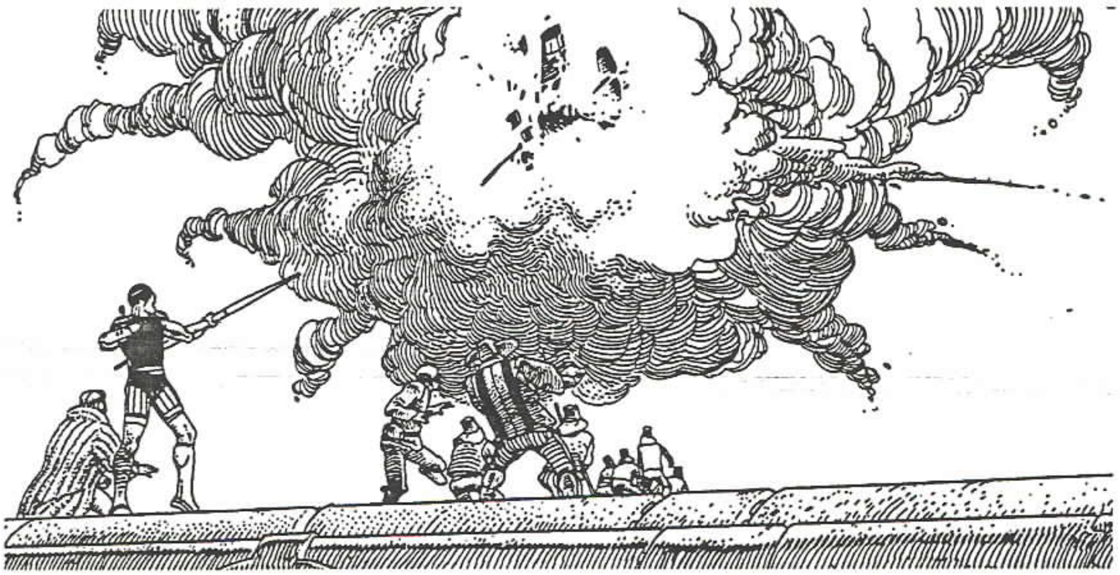
3. Use all those little details in the silhouette to make the shapes appear to move as you want them to, for instance, to make the billows rotate downward.

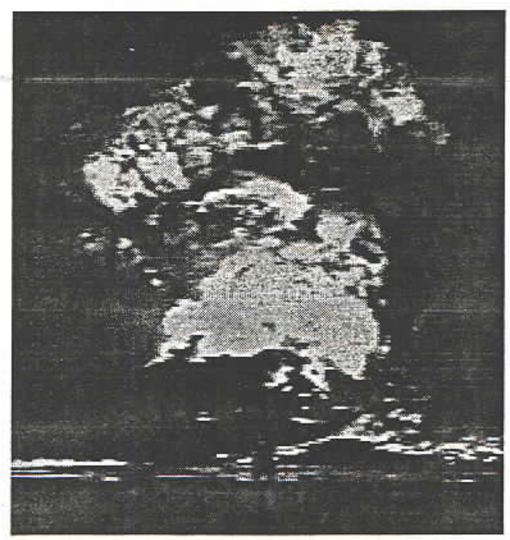
A lot of the same rules for billowing smoke apply to other effects as well as smoke. Dust, steam, even masses of bubbles under water can take on the same shapes provided the arrangement of forces are the same.

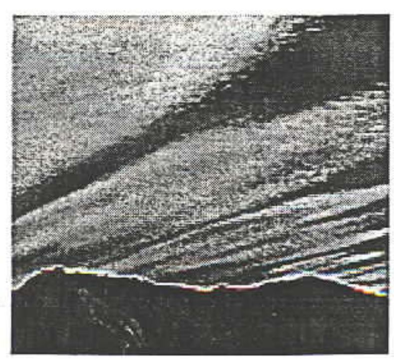
In the case of an avalanche, the primary force is not heated air but sliding snow:

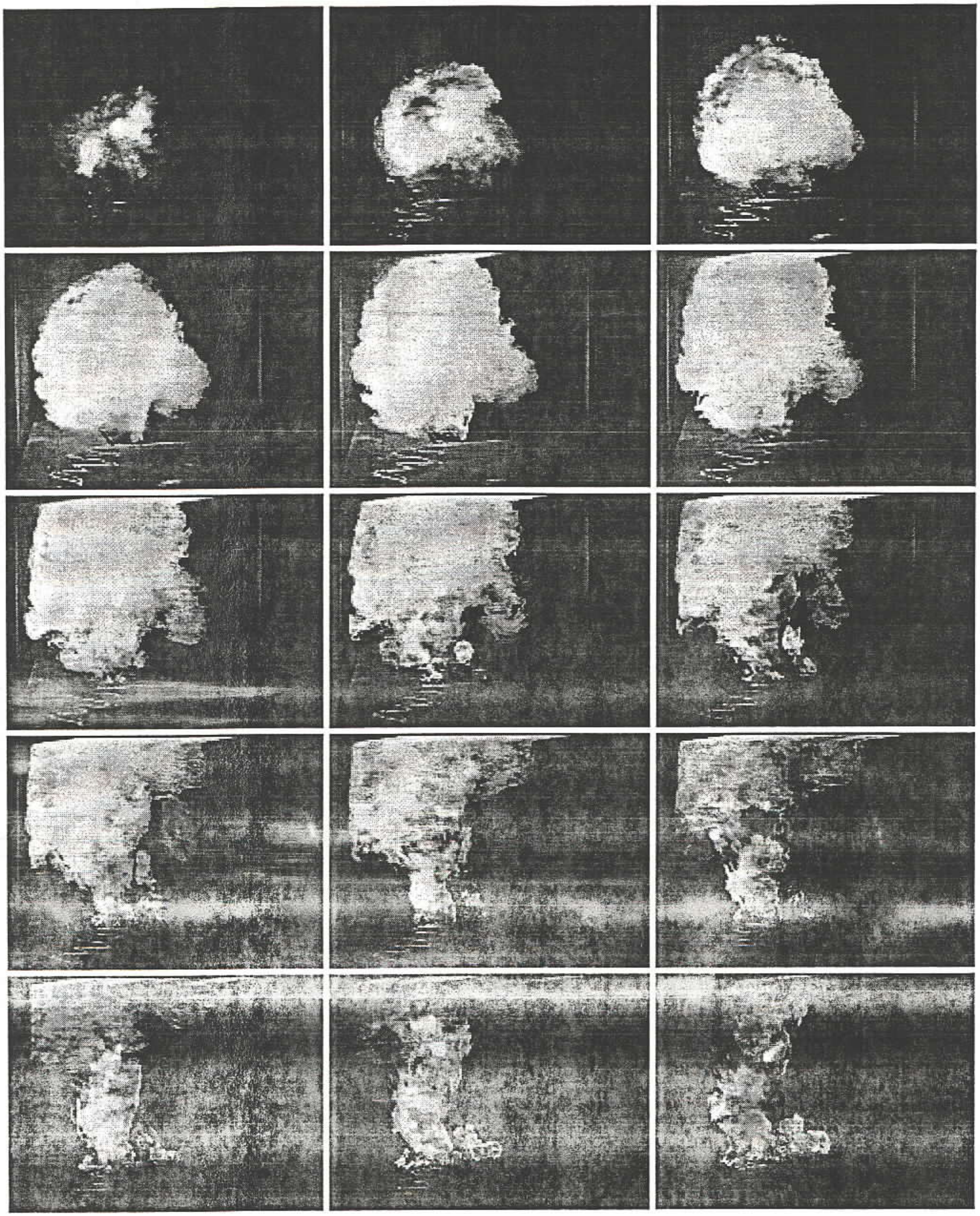


Some Smoke Shapes

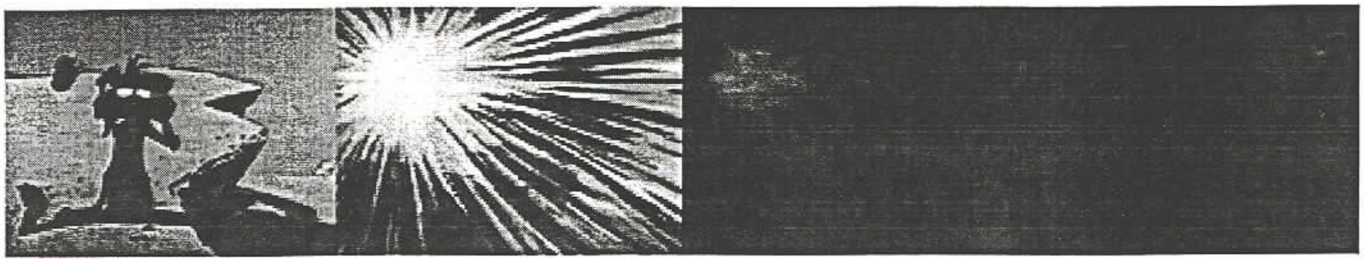






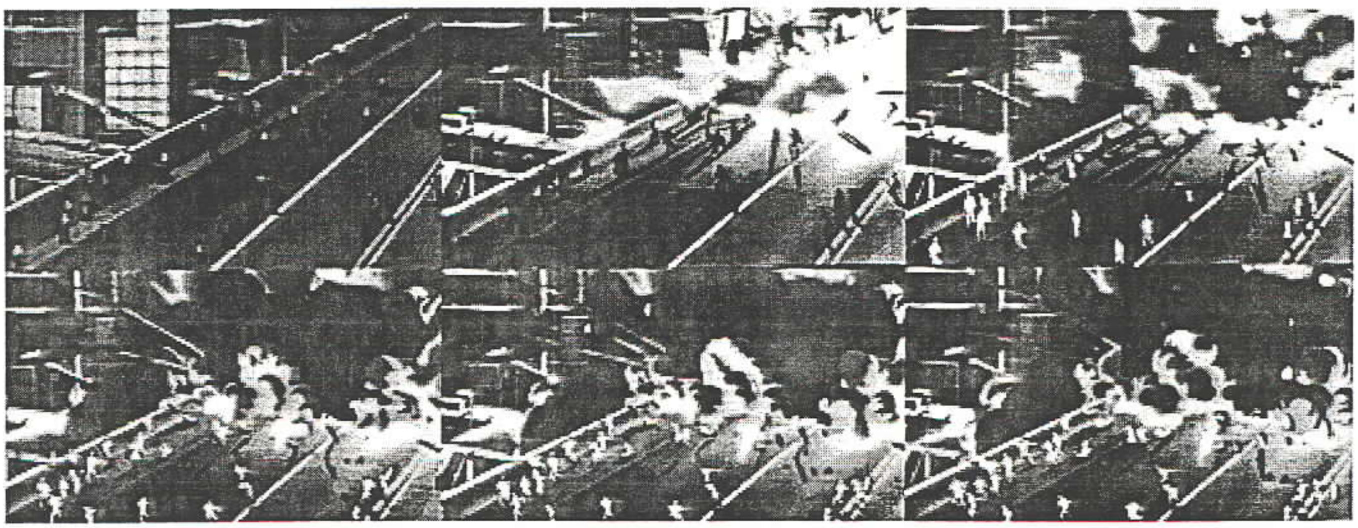


Explosions, flash frames, rimlites, and other tricks



When Chuck Jones needed to blow up the Coyote in as violent a way as possible, he realized that even on ones, the fastest explosions looked too slow. Instead, he found that if he started with the explosion filling the frame, and shrunk ~~the~~ it in a few frames into nothing, it would appear as of the blast was so powerful that all the outward motion happened within a single frame.

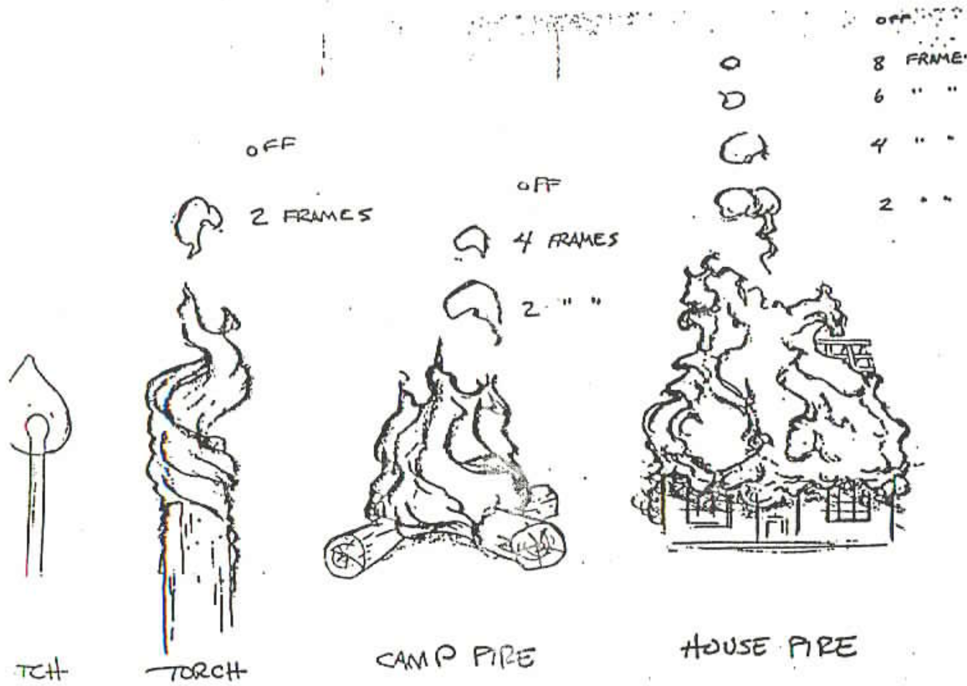
In timing explosions, a way of increasing the perceived violence is to carry out most of the action in the first few frames, and then drifting the action from then on. For instance, successive frames of an explosion in the movie Akira:



There are all sorts of little "cheats" in Efx, not the least of which involves single-frame effects which leave an impression that something happened without the viewers really being aware of just what they saw (subliminal entertainment.)

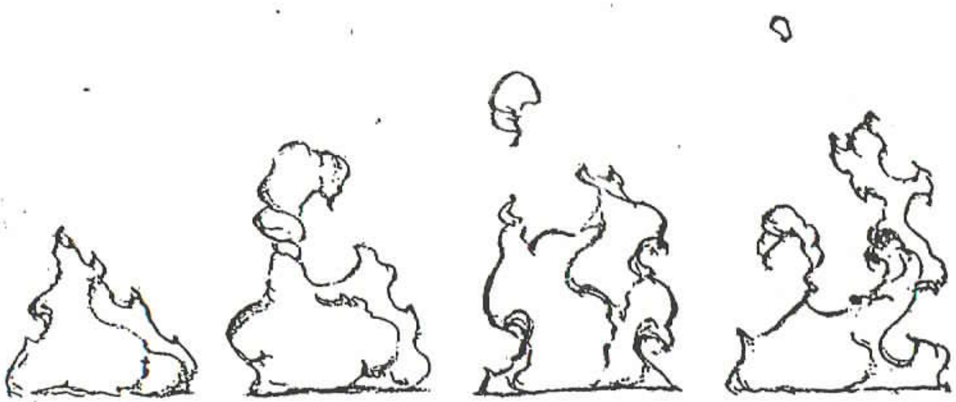
A good example is the flash frame. Sometimes a single white frame is inserted during, say, an explosion, to add impact. You don't see it unless you know its there, but it has a huge effect on the feel of the scene. Sometimes two fire cycles can be overlapped to create a much more complex set of shapes and exposures, and if the cycles are not of the same length, the shapes don't repeat themselves. You can imply a lot of fire sometimes by putting rimlites all over the place, as if the fire is just off-screen. Rimlites only take a few held mattes with a flickering exposure to look great, and you've implied a lot of fire without showing it. There are endless ways of saving work and at the same time making a scene look better, and what it really boils down to this, the cardinal rule of Special Effects:

If it looks good on the screen, it doesn't matter how you got it there.



RULE OF THUMB -

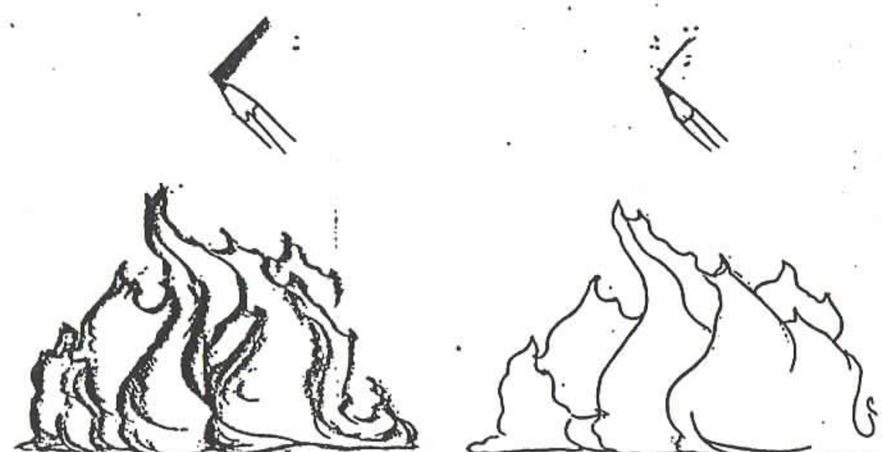
THE DETACHED PORTION OF FLAME WILL LAST DIFFERENT LENGTHS OF TIME FOR DIFFERENT SIZES OF FIRE. IF, FOR INSTANCE, AN ANIMATOR KEEPS A DETACHED FLAME FOR 8 FRAMES ON A TORCH, IT WILL NOT APPEAR NATURAL.



WHEN DOING A FIRE ASSIGNMENT FOR TRAINING, ALWAYS DO THE THREE BASIC TYPES;

1. TORCH
2. CAMP FIRE OR FIRE PLACE
3. FOREST FIRE OR STRUCTURE FIRE

THIS WILL FORCE YOU TO TEACH YOURSELF THE DIFFERENCES IN TIMING BETWEEN EACH.

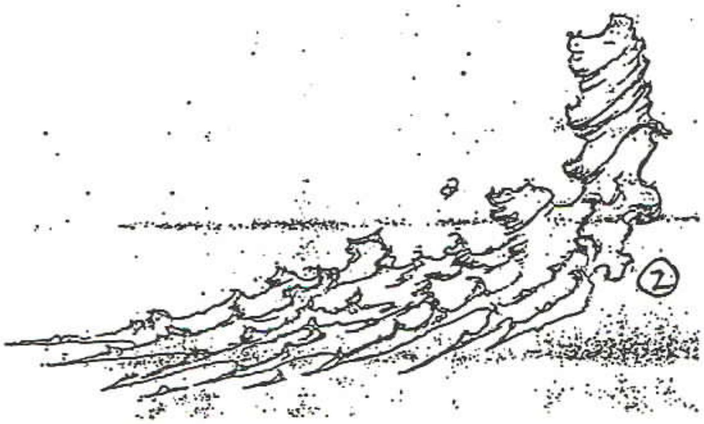


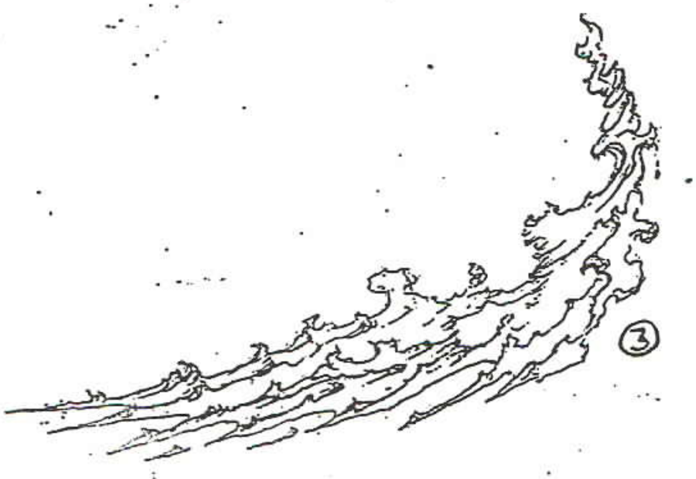
USE SIDE OF PENCIL TO RUFF OUT FIRE. THEN SELECT THE CORRECT LINE THAT WILL DEFINE YOUR FLAME.

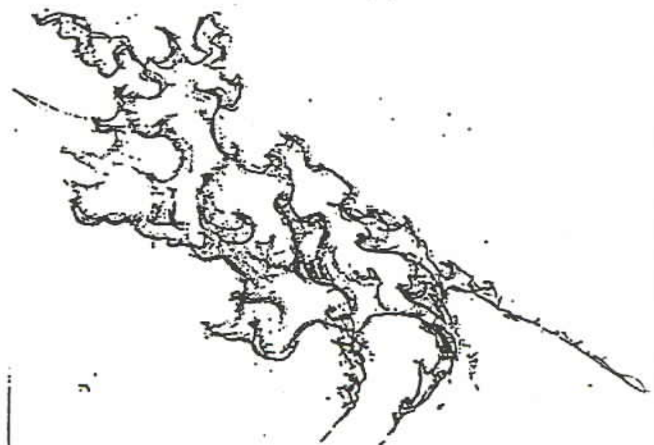
USING THE POINT OF THE PENCIL TO RUFF OUT FIRE RESTRICTS YOUR CREATIVITY

DON'T RELY ON THE PRINTER TO ANIMATE. YOU'RE JUST COPYING, NOT UNDERSTANDING. BY LOOKING AT A VIDEO OF LIVE FIRE OVER AND OVER, YOUR MIND WILL BUILD A MEMORY OF THE TIMING AND PHYSICS OF EACH TYPE OF FIRE. AFTER VIEWING A PIECE OF LIVE FIRE OVER AND OVER, TURN OFF THE VIDEO AND SKETCH A SERIES OF WHAT YOU SAW.

AN EXAMPLE OF FIRE DESIGN







<u>**Impact Dust**</u>

Ed Coffey

"The Lion King" and lots of other films take place in very dusty environments. All a character need do is sneeze in a scene and the Director seems to want a cloud of dust to occur. (Don't argue, just do it)!

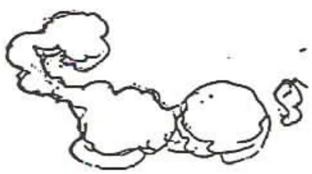
At the point of impact, dust comes up fast in just a few frames, then slows down progressively. Your hopefully beautiful design can sort of hang there, so the audience can go "ooh" and "ahhh".

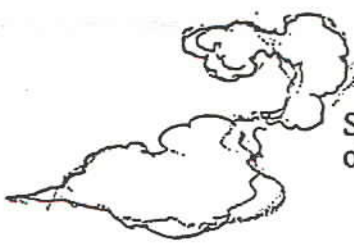
Dust Progression:

Do these scenes rough first. Think in terms of 3-D while you design.

Think ground plane. The dust cloud needs to fit convincingly on the background.

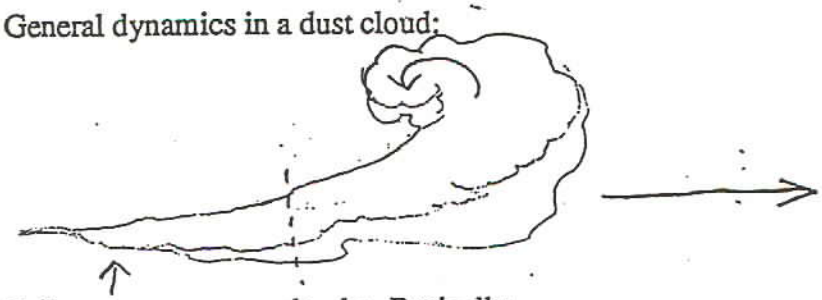
Your design may hang in the air for some time, so make it pleasing. Think of it as sort of an over-the-top pose in life drawing class, except that the model never quite comes to a complete stop and is slowly disintegrating:





S-curves, crescent shapes, mildly obscene little negative shapes abound.

General dynamics in a dust cloud:



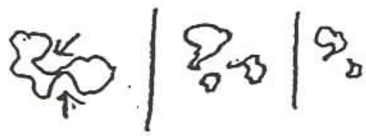
Move out away from impact.

Tail part moves <u>very</u> slowly. Basically just thins out if scene is long enough.

Dissipation

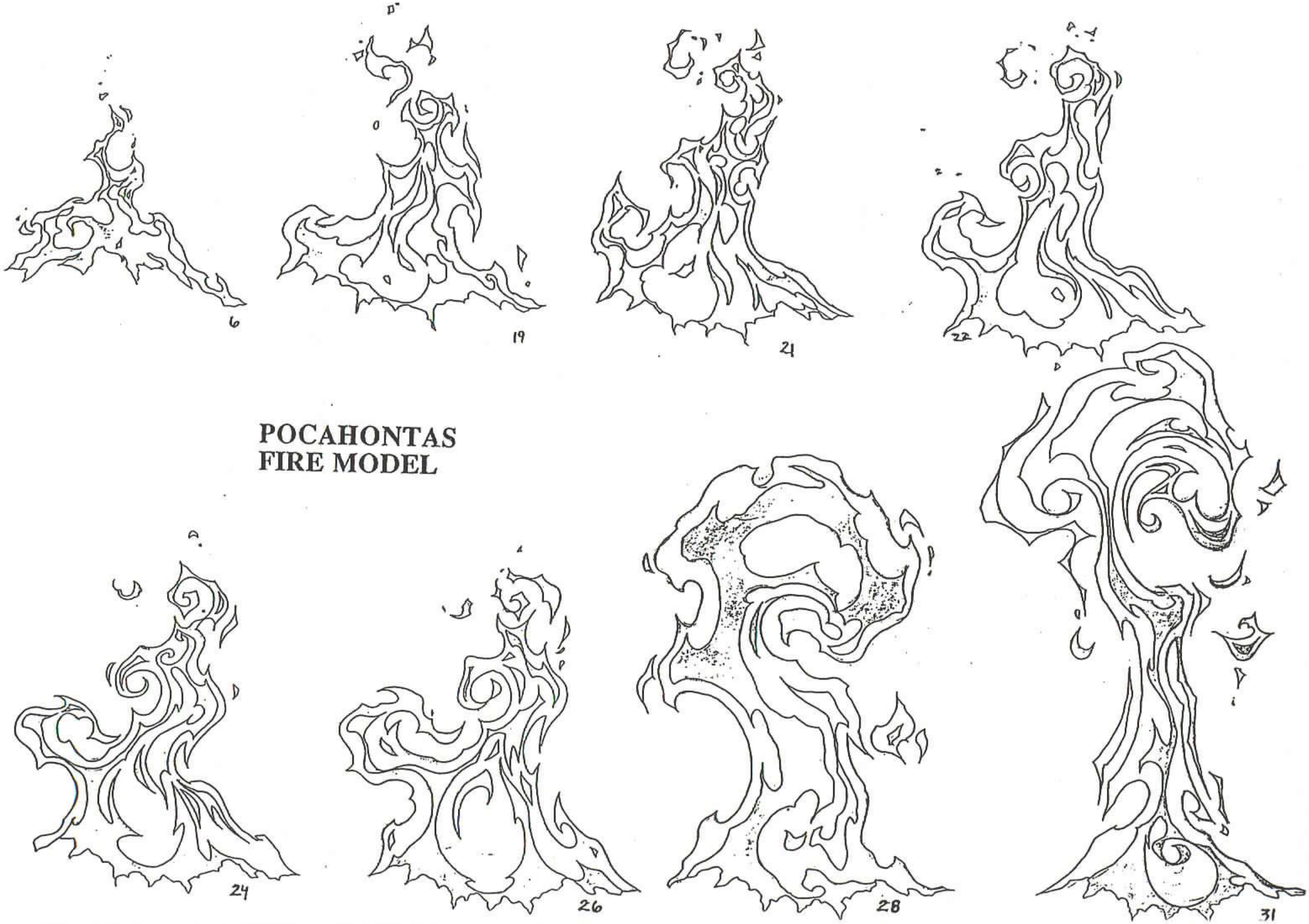
If the scene goes on forever, significant dissipation of your dust is required. Do not just make concentrically smaller blobs while entire unit is still moving. Have one area "bite" into the shape faster than the rest of the reduction:

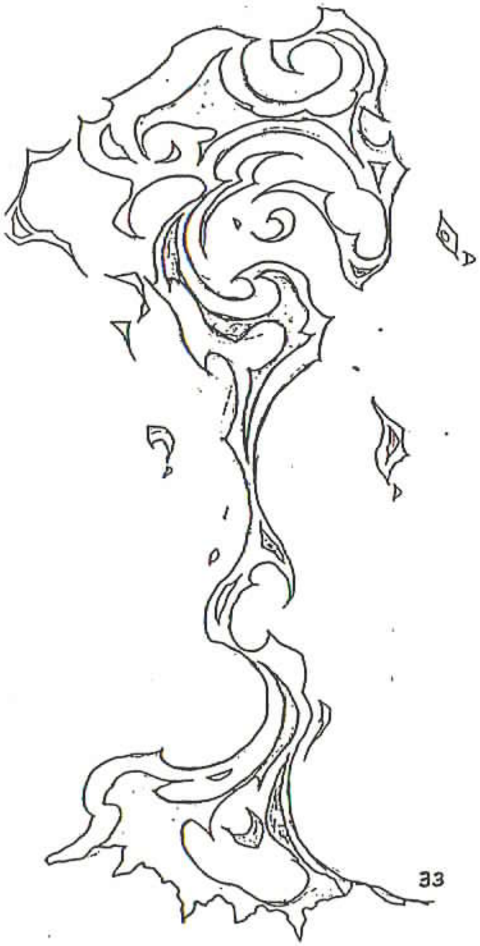
Then add other "bites".



Variations on all of these notes can and should be made. Do what's required for the scene. Follow Director's requests, etc.

POCAHONTAS
FIRE MODEL





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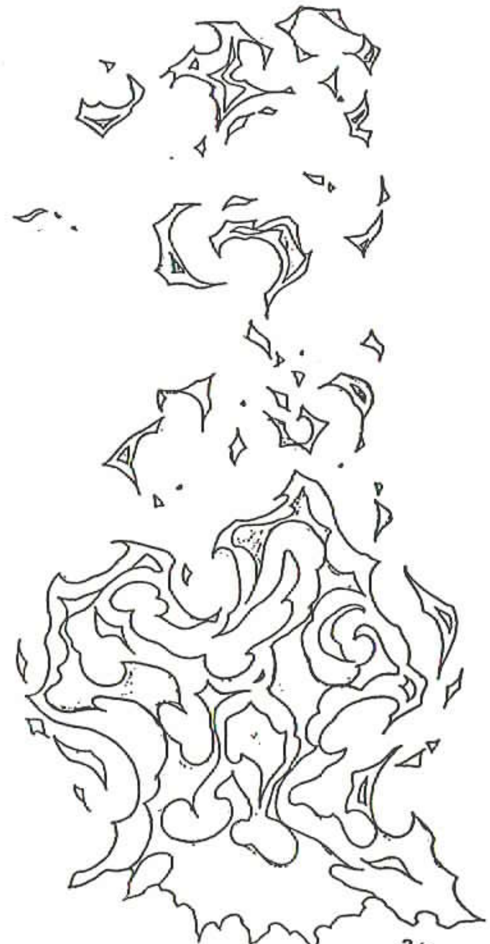

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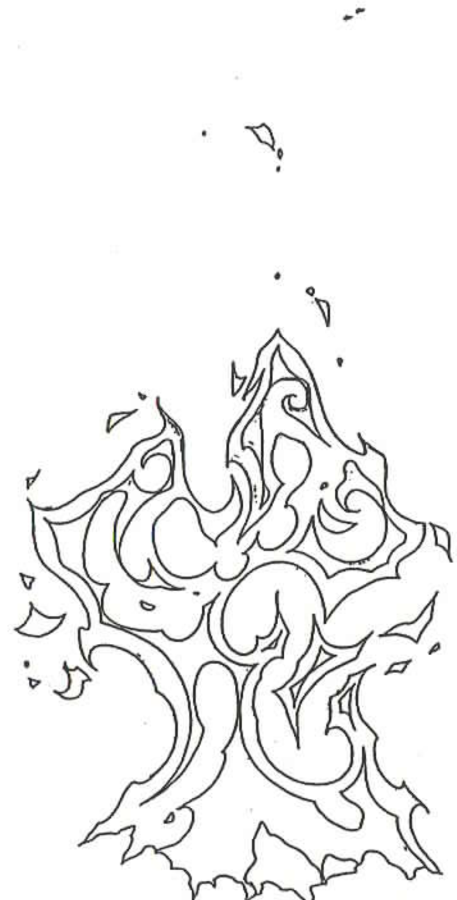

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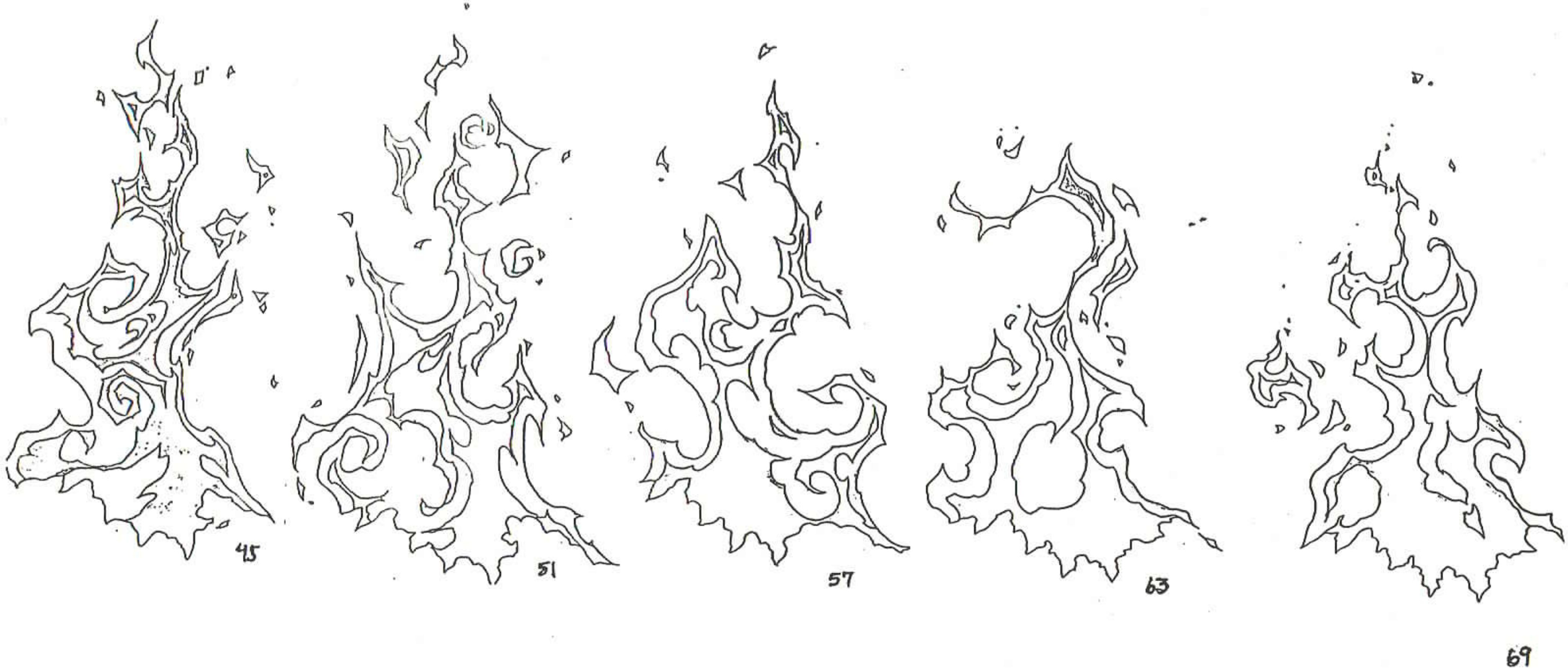
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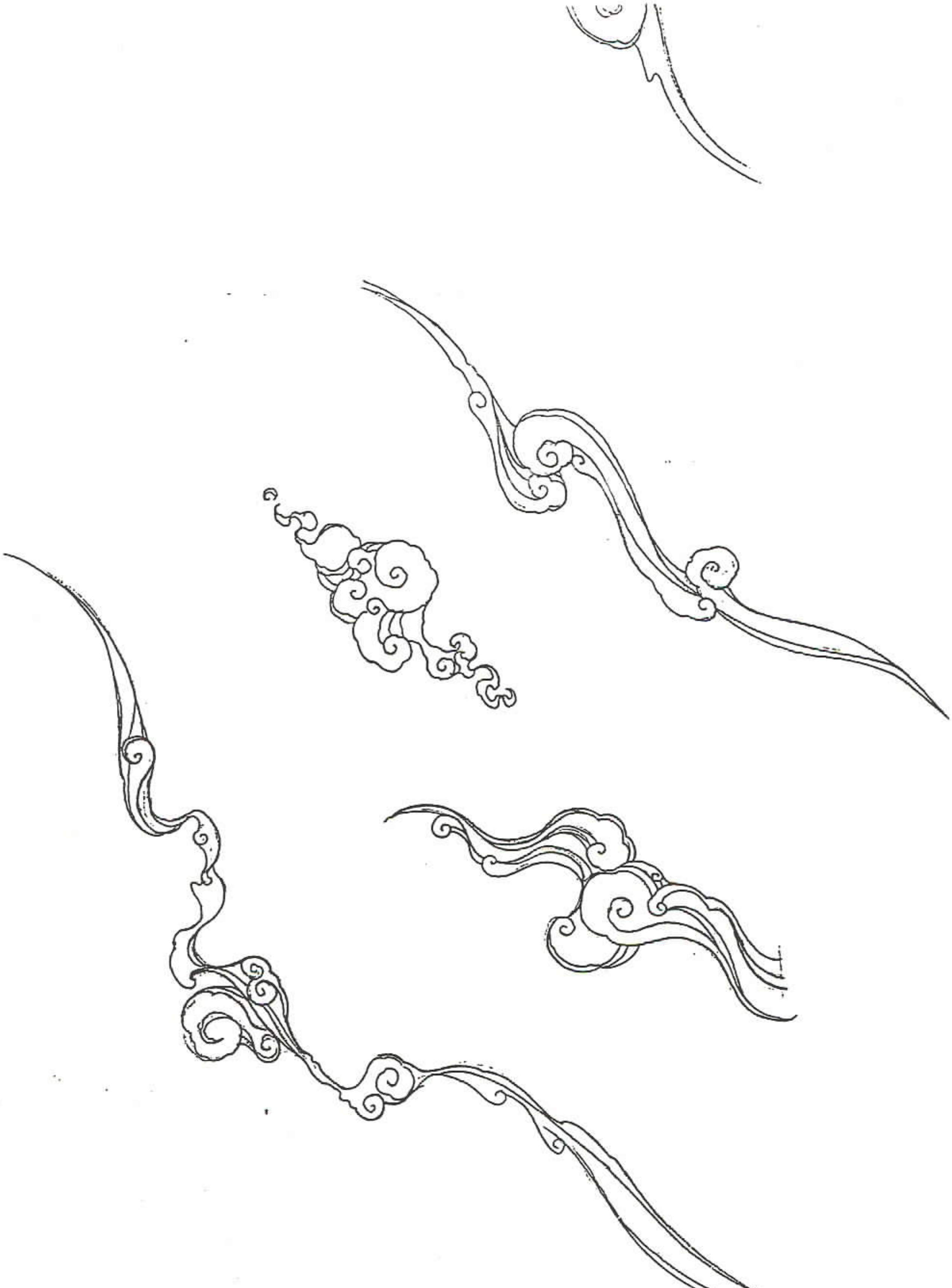
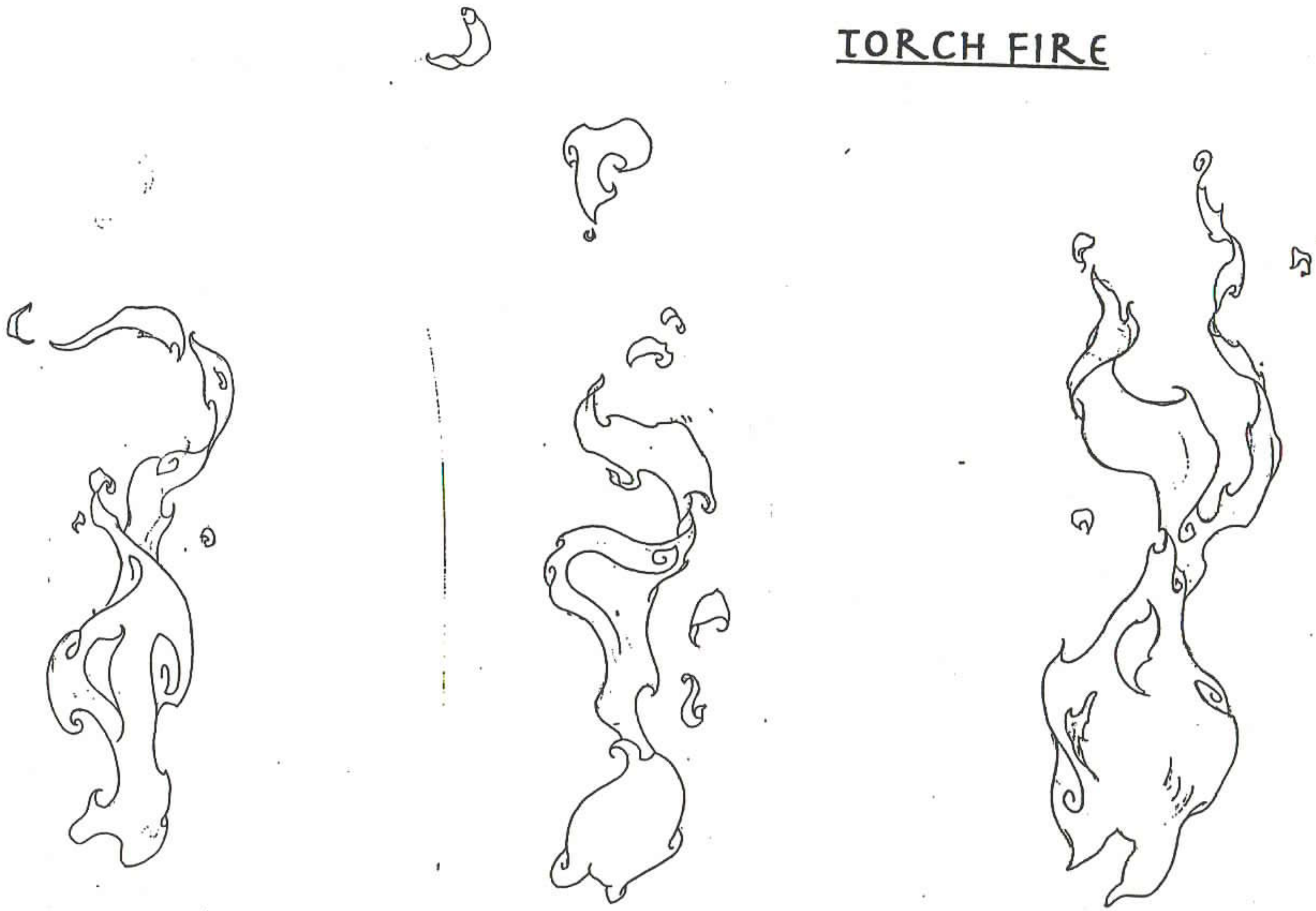


TORCH FIRE



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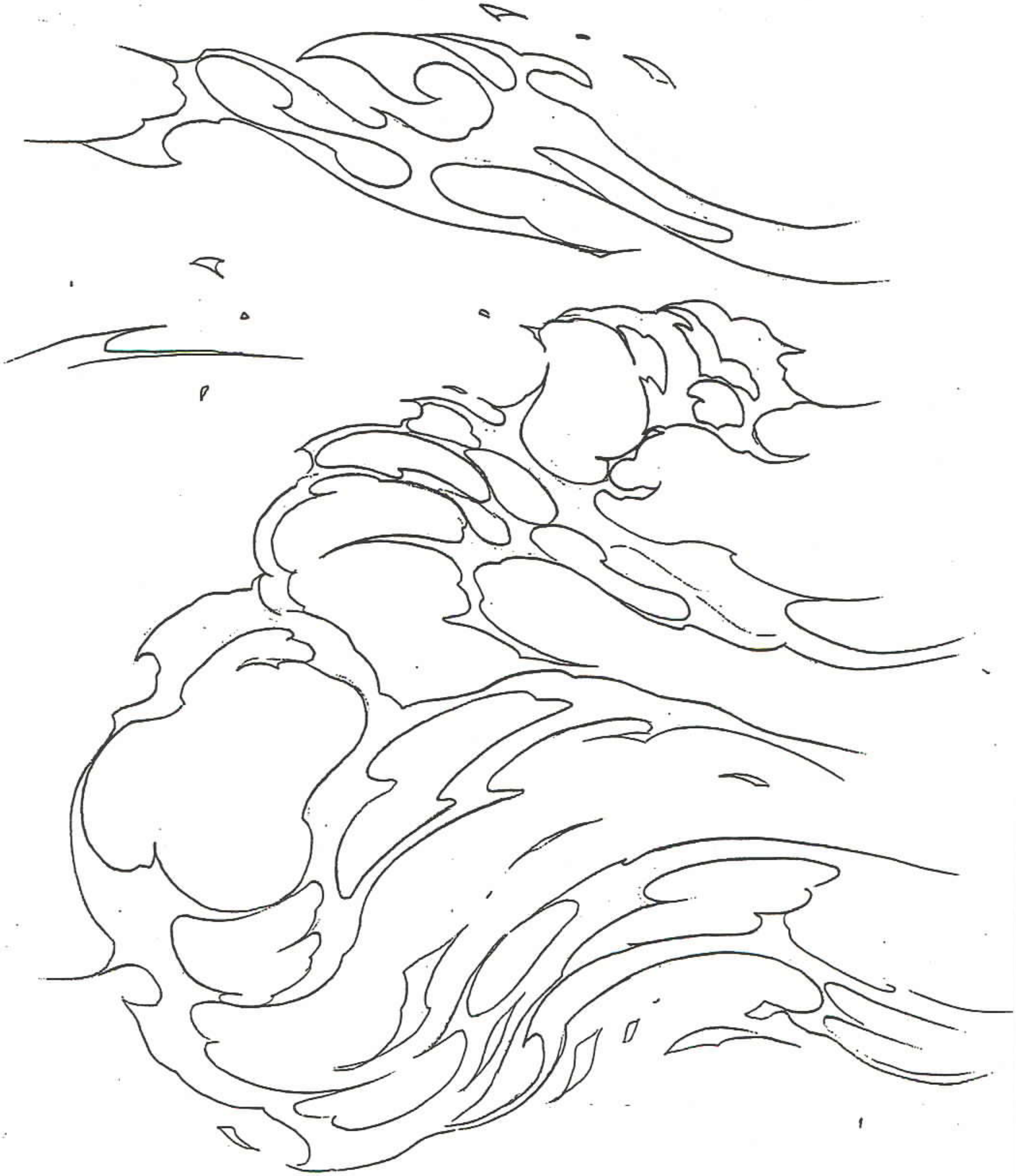

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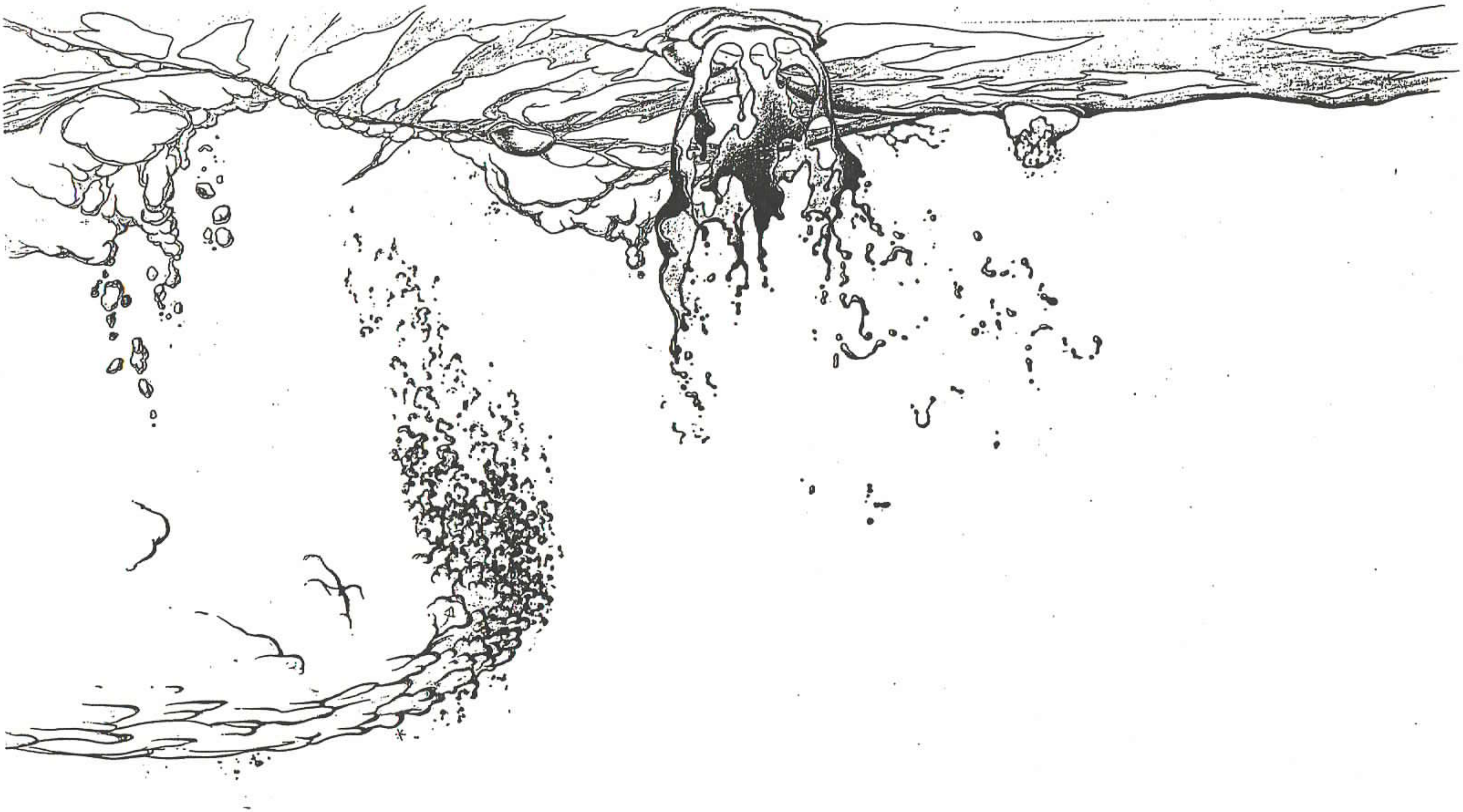
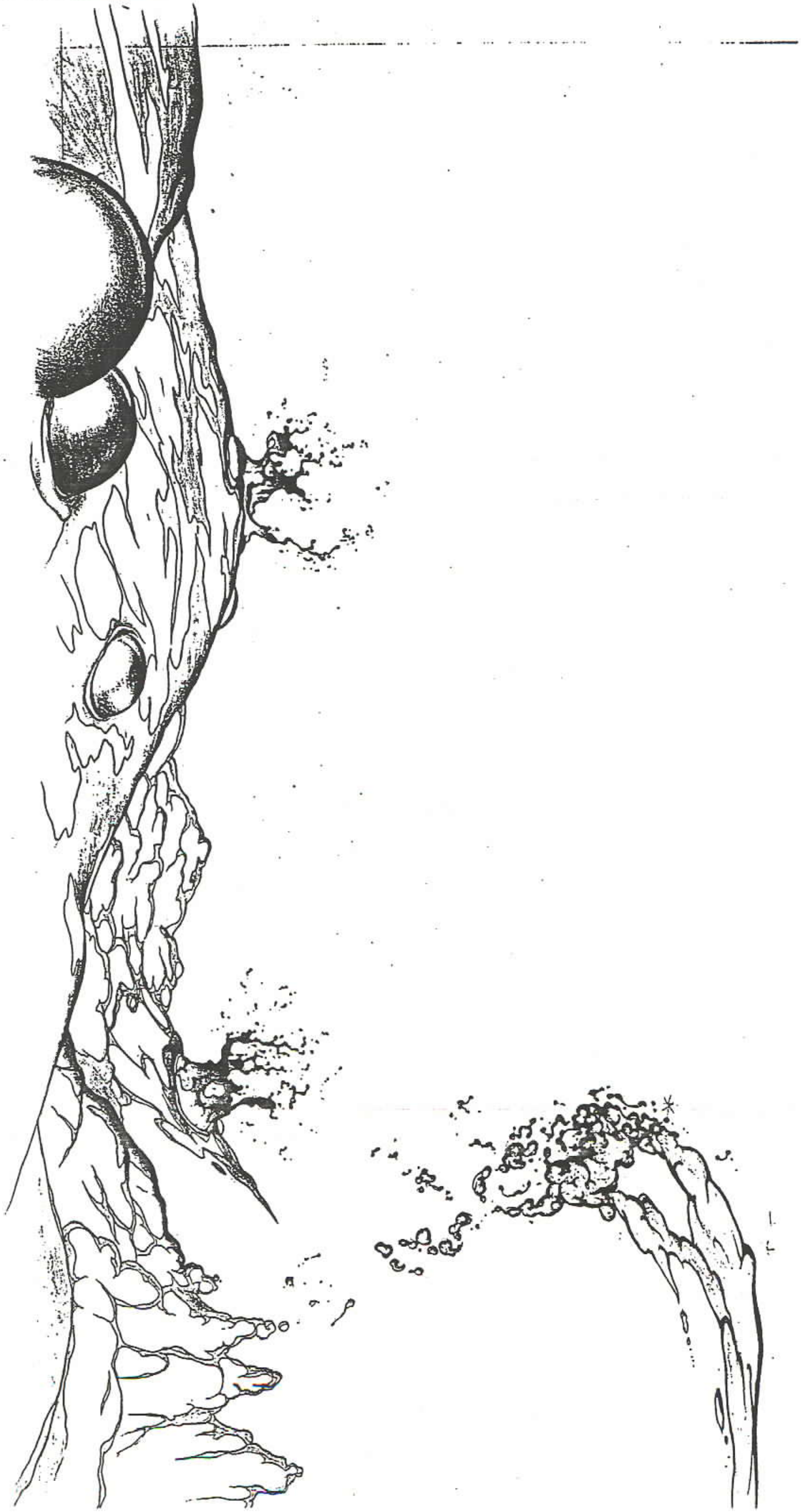
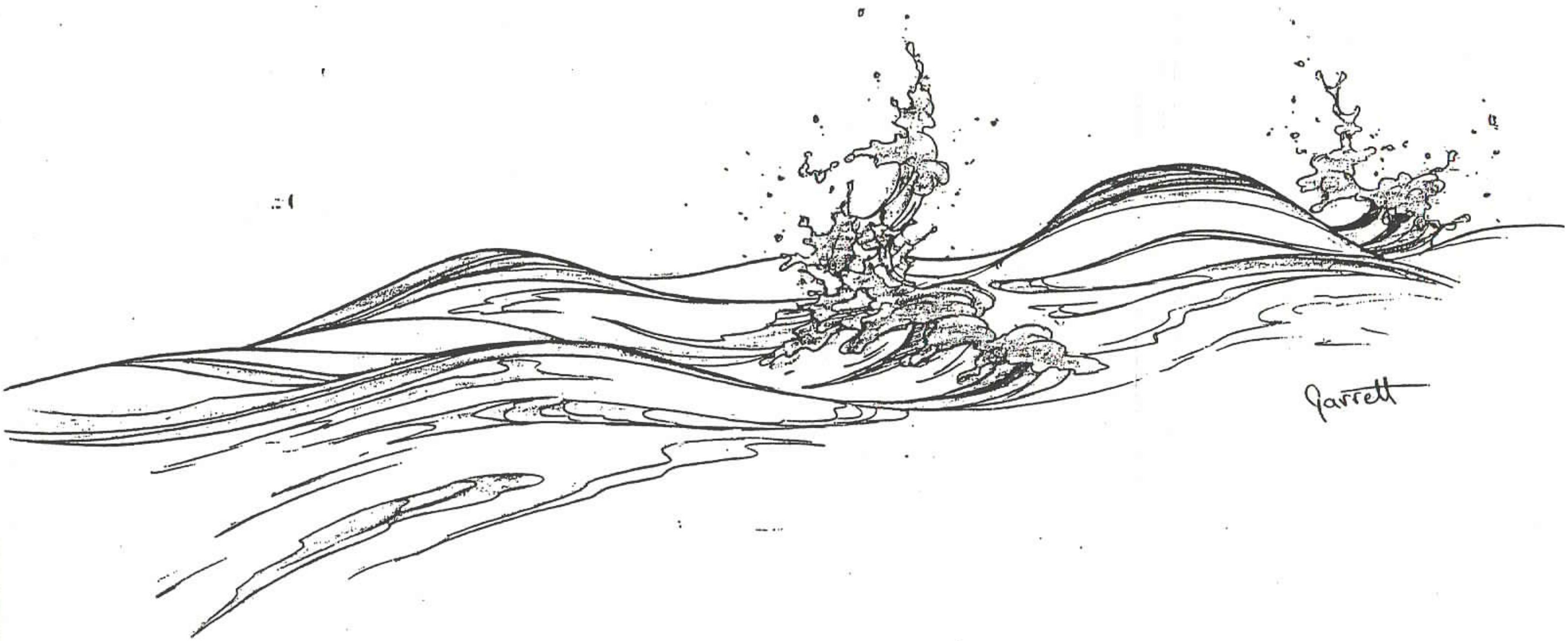
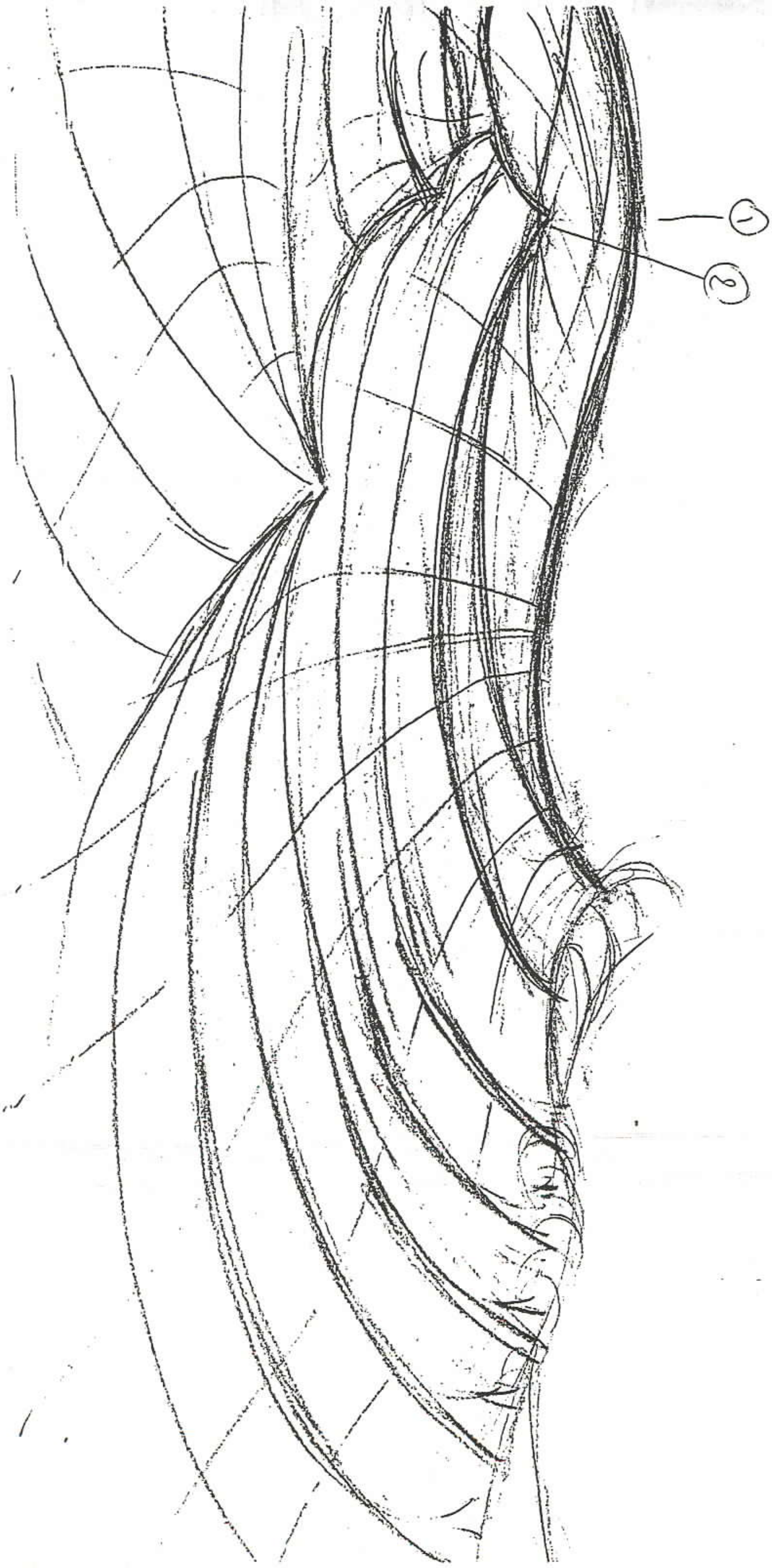





Garrett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(1)

there isn't a real interest or knowledge in natural phenomenon, their work will appear to be imitation animation. Lacking soul. Unattractive. As a tracing of art.

A musical analogy may be that if a person, without musical interest, memorizes a piece of music for the piano and hits every note (and rest) exactly as written, the music will sound cold and technical, unattractive, lacking soul. As if it's a tracing of the music. The music, played by a person whose interest is music, will have the spirit of the music, the intangible "soul." Music played by one whose heart is in the music will play the music with heart. Music with heart is more interesting and therefore more attractive, having the many subtleties that give the music spirit.

An interest in, and a study of the natural world, will create a knowledge of things which will then be the foundation for your art... effects animation. Your art will be as interesting as your *interest* in the world about you. It's not about "doing effects." It's about the interpretation of natural phenomenon as illustrated in your effects animation. You want people to be attracted to your work but... the joy of the *doing* is the first reward! It's "showbiz." It's art!

I want to...want to!

To desire the adulation, money, attention and all those things slathered on someone who is a "STAR" is not enough. The desire is a beginning but the "star" earns the slathering because of the contribution made to the art. One makes a contribution by having the talent, a passion, motivation, knowledge of the craft, an interest in the things which are required to do the work of the "star." A passion for the work, the art. Wanting to want to is not enough!

Opened...Closed.

The closed container will accept no contents until it is opened. Wow! Is that a neat thought? What has this got to do with animating effects?

Well...You are a container. The more open you are to ideas, to other people, to working, to learning, to growing, the better you will be at fulfilling your desire to be an effects animator, or anything you want to be. To be open is to be in "creative neutral." It's not a selfish thing, not a

grasping thing, but more like a sponge, absorbing the knowledge around you.

The moment you decide you know everything will be the moment you stop learning anything. You will be closed. De-energized. That will also be the moment you are not interested in anything and therefore uninteresting to your fellow artists. Lonely times ahead! Be open! There is much to learn and experience. You, as a container, will never run the risk of overflowing if you are open.

Passionate*...Capable of or having intense feelings.*

Most of us have been taught to hold a tight rein on our passion. After all, unbridled passion can lead to murder and mayhem! Gees! Yet, if we hold onto our passion too tightly we risk being that closed container, unopened for business, unmotivated. The trick is to be civil and channel our passion, temper our passion, so that it works for us. Enthusiasm, fervor, zeal, all are emotions that can generate energy which can be directed toward your goal. Being interested in something creates an excitement, an energy, a passion. We've all felt the energy generated by the act of buying something new. Being passionate is to be open. Being interested in your work, with a passion, will energize you and help you to succeed at what it is you want to do.

The blank sheet of paper (or blank monitor screen)

Starting with that first blank space, you are going to create animated effects which help to propel the story to new heights of believability. Now with a task like that you want to be good at it. And to be good is to be motivated.

Dorse A. Lanpher
Walt Disney Feature Animation
2100 Riverside Dr.
Burbank, CA 91506

Effects Animation Notes from Dorse

***Study Reference**

Study live action and live action effects. Shoot Video Collect Photos Consult with the Animators who are already successful.

The more you know about everything, the better your effects will be and the more fun you'll have. Train yourself to see "effects" around you in your day-to-day business. Note the reflection on the water in your drinking glass, the steam from your coffee; the little things and the big. Make mental pictures!

***Visualize**

Your brain is a computer in which you've stored all your experiences. If you search your memory banks, you should be able to come up with a past visual which may be close to that effect you want to animate. Visualize it in your "mind's eye". See it in your head.

***Thumbnail**

Sketch extremes of the effects in your scene. Layout the progression of the effect. Create kind of a road map in your mind of the scene you want to animate. See it before you start animating.

***Keep It Simple**

Remember, "editing is the great art"! What you leave out is as important as what you put in. You will never have enough time to animate a splash with every drop which might actually occur. An effects animator is an "abstract impressionist". We want to give the audience an "impression" of the effects. Caricature nature.

***Think Story**

What is the story you want to tell the audience with your effects. Is the mood you want to convey angry, violent, serene, sad, mysterious? Your effects can help convey the mood of the scene you're working on. How does the effect evolve in this scene? Will it start with a bang and simmer down? Should it hook up to another scene? Ask yourself questions about your effects and come up with answers. What's the story?

***Be Inventive**

The paper in front of you is where you'll create your world. Well, maybe, the director's world. But you hold the magic wand to give life to the effects. Think forces. Everything in the universe impacts everything in the universe. Does this push that? Does gravity pull this down while a pressure forces this up? Doe this one hit and tumble and this one slide? As you animate, continually ask yourself questions like this that pertain to the particular task you're working on. Think about it! The waterfall you're animating: What is it we see when looking at a waterfall? What is our Impression?

***Think Design**

Big against small; straight against curve. As an abstract impressionist, good design will be a tool you use to animate effects which are attractive. That is, effects which people will want to see, enjoy seeing and, hopefully, will want to see over and over. Overlap action; things going up while things go down, fast against slow. "Texture" your timing; "texture your design.

***Go for it!**

"ANIMATION NOTES"

We should be like sponges - remember things, places, situations - pay a lot of attention to those things around us- especially people.

Have a good ear for dialogue and how it is delivered.

1. An animator should be like a good writer. He should be able to state clearly what he has to say. The message or view point or story point must come through. And it must be done in an interesting and entertaining way.

2. He/she must be an actor (animation is acting on paper). Must portray all parts: male, female, human, animal, or whatever. Must act all parts: young, old, familiar or unfamiliar, or whatever the emotion.

3. Must be director, directing placement and movement on paper - loudly, quietly, dramatically, etc., just as a director handles real stage. Audience must know where and when characters and story is at all times.

Technique or style is not so important - that will come out while putting over the idea.

Don't illustrate an idea - caricature it.

Get good "Marriage" of dialogue and drawing.

Drawings should be staged so the silhouette is plain to see. Negative and positive shapes should be used to create simple pattern so idea can be gotten effortlessly.

Every story is full of causes and effects or action and re-action. There should be no doubt about what the cause or action is - likewise no doubt about what the effect or reaction is.

No matter how much a character or an action is caricatured, it must still have its own logic.

A climax or crisis in an action, scene or story should be treated like a crescendo in music. Arriving there too soon will spoil the ultimate dramatic effect.

Do not draw with the fingers - draw with the noggin. Draw what you know of a thing - what you know it looks like. Draw from inside out.

Practice caressing objects mentally - anything. Faces, things, compositions, etc. See with the mind, not the eyes. Don't just see things - think things, get the facts - the information.

Be aware of texture, volume, shape, movement.

SOME DON'TS

Don't ever fall in love with one of your drawings. That will make it difficult for you to change it. Always assume that a drawing can be improved.

Don't work blindly. Know how your scene fits into the story - what it is saying.

Don't go a day without studying something for its character, construction, how it occupies space, how its straights work against its curves, etc. Keep your eyes looking, seeing. In tennis one of the basic rules is to watch the ball right up till the time it contacts the racket. Some gung-hoers carry a tennis ball with them - in the car, in the office, etc., to practice watching the ball. Some even concentrate on watching the seams on the ball during play. Why? Because it is so easy to forget to watch the ball. Likewise, it is easy for an artist to forget to see.

Don't be stingy... Share your animation and drawing problems with others. A typist learns the keyboard and that problem never comes up again. An artist has a new problem with every drawing - every day, every week, every year, all through life. You help yourself and others by sharing your drawing problems with others. It keeps you learning - it keeps you from unlearning.

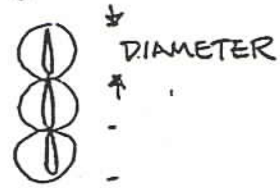
Don't consider an inbetween less important than an extreme. Both are necessary. If 75% of the drawings in a scene is inbetweens, that means 75% of the viewing time on the screen is spent watching inbetweens.

Don't mistake a clean, fine-lined pretty drawing as the only criteria for a good clean-up drawing. A good clean-up drawing is one which has good texture, whose parts vary interestingly in regard to size, space relationships, whose parts relate properly to one another and whose whole relates properly to the drawings around it, animation-wise.

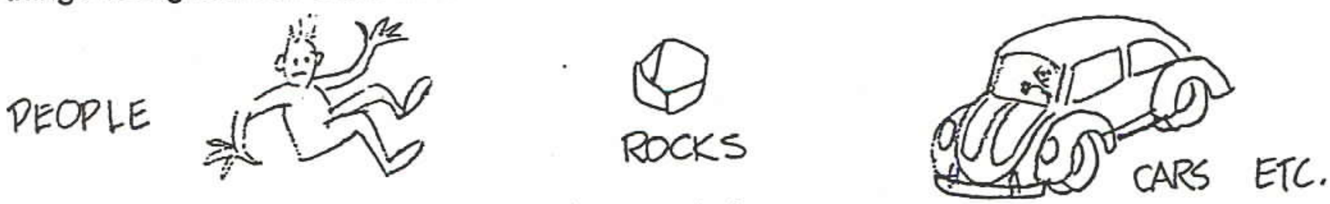
NOTES ON TIMING EFFECTS - FROM DORSE

There are several ways to think about timing. Ultimately, we want to develop a "sense" of timing so we can animate effects without struggling with the mechanical aspects, much as the concert musician performs the concert without counting out loud " 1, 2, 3, 4 -- 1, 2, 3, 4 -- 1, 2, 3, 4."

A good general rule, thus stated, is "Everything moves the distance of its own diameter each 1/24th of a second or frame of film." For example, we'll use a shape which we think of as a raindrop. Each raindrop moves the length of itself each frame. (Each drawing on ones)



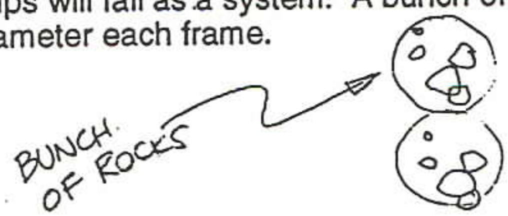
On "twos," of course, it will fall twice the distance of its diameter. This rule only applies to things falling here on earth where we have air resistance and gravity.



This is a general rule. A starting place for your timing.

Things which are projected, hurled, thrown or blasted will move faster than this until gravity takes over or air resistance takes over (feathers, bubbles, etc.).

Things which are falling in groups will fall as a system. A bunch of rocks falling together will fall the distance of the system's diameter each frame.



A more obvious timing method is to visualize the effect you want to animate and count seconds as you see it happening. "Thou-sand-one, thou-sand-two." (This requires some practice to get the rhythm. It's helpful to use a stopwatch or wristwatch.) By saying "thou-sand-one," in the correct time, each syllable will equal 8 frames. The whole thing, "thou-sand-one," will be equal to 1/24th of a second in 24 frames, if your rhythm is correct. You can tap your pencil as you count, "thou-sand-one, thou-sand-two," etc.

The timing of our effects should be treated as another design element in the scene (fast against slow, etc.) not necessarily a duplication of reality but a believable artistic version of a fantasy. No matter how pretty your drawing is, if the timing isn't working the illusion is destroyed.

ON INBETWEENING *
SPECIAL EFFECTS

THE INBETWEEN

The inbetween is a transition drawing between two extreme drawings. The extremes are the storytelling drawings and thus hold the essence of an animated action. The inbetweens fill in the action between these key drawings (still retaining their essence yet never distracting from or overpowering them).

TEN SIMPLE STEPS TO A GOOD INBETWEEN:

1.) Look at the timing charts
2.) Roll the extremes & plot the arcs
3.) Turn on the backlight & put the drawings in flipping order
4.) Now following the arcs and charts, build your foundation by drawing the shapes between the shapes and the lines between the lines
5.) Turn off the light
6.) Flip the drawings and build a solid 3-D drawing on your foundation
7.) Put the drawings in rolling order and re-check the inbetween
8.) Turn on the backlight
9.) Shift the drawings off the pegs to check volumes and inbetween details
10). Fix the final problems, using both the light & flipping

As you can see, inbetweening is a simple and logical process. And by following these steps your inbetweens should take less time, be more accurate, and be well drawn. For a more detailed look at each of these steps read on.

IMPORTANT

Before inbetweening an effects scene, a series of questions should be asked (and answered) about the scene:

1.) What is going on?

Find out what is happpening on the other levels of the scene, what's happening in the story, and what mood should be established by the animation. This can have an important effect on the inbetweens.

2.) What does the scene look like?

Look at the perspective of the layout, the size and placement of the characters, the direction of the light source, how big the effects you're drawing are, how far away they are, and anything else that relates to the scene.

3.) What are you drawing?

Is it smoke, fire, oil, water? How big is it, and how slowly or violently is it moving? Remember, each kind of object or material has a different way of moving so it will be inbetweened differently. (Some things, such as a candle flame, may not actually inbetween at all.)

Finally, solutions to most problems can be discovered using common sense, memory, and experience. There may not be a stock answer as to how a rock breaks apart, but by using logic, physics, and reference from nature, it's possible to work out a solution without having to ask for the **"Right"** answer. Use your head! Think out the problem and then solve it!

But.... if that doesn't work, don't spin your wheels. Go to someone more experienced, they can usually come up with a solution much quicker than you can.

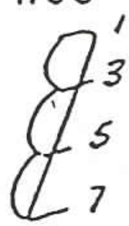
1.) CHECKING THE TIMING CHARTS

The timing chart is guideline as to where to put your inbetweens. It is usually located in the upper right hand corner of the extreme drawings, and in many cases there may be separate charts for different parts of the same drawing. Some animators also vary the location and style of the charts, but generally they fall into the following categories:

1/2

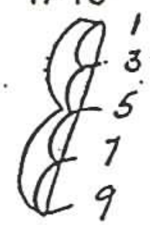
(3 is halfway between 1 & 5)

1/3'S



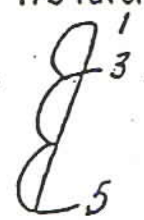
(3 is one third between 1 & 7, 5 is halfway between 3 & 7)

1/4'S



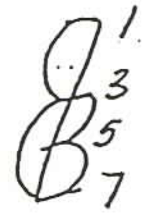
(5 is halfway between 1 & 9, 3 is halfway between 1 & 5, 7 is halfway between 5 & 9)

1/3 favor



(3 is one third between 1 & 5, favoring 1)

1/2 &1/4



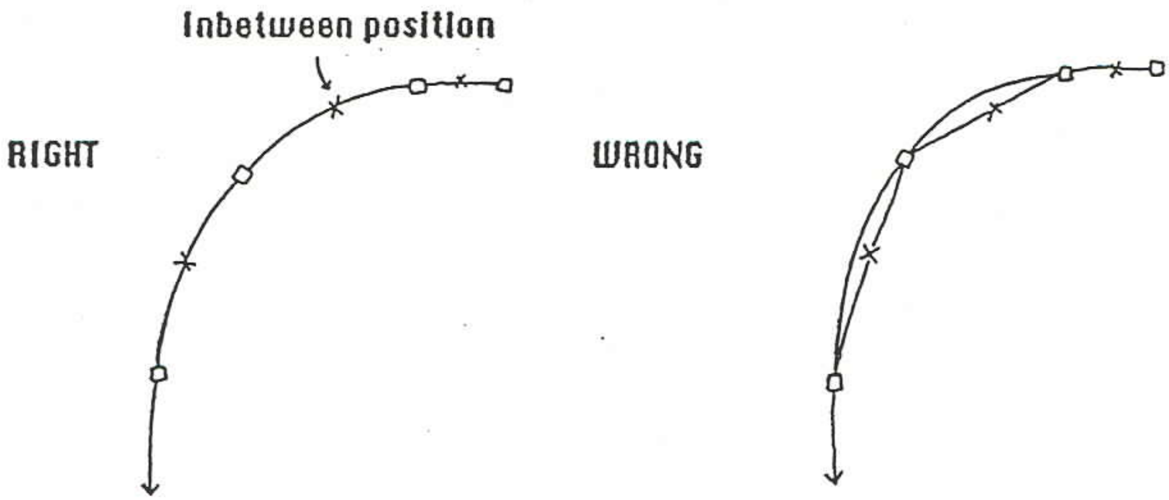
(3 is halfway between 1 & 7, 5 is halfway between 3 & 7)

Some animators also call for inbetweens favoring the extremes. In these cases you have to use your own judgement, based on how the chart looks, as to where to put your inbetween. But when the timing chart calls for a specific timing ie:(1/2 way between the two extremes), there is only one place it can be, exactly where the animator called for it. If the inbetween doesn't follow the charts, it is wrong. **Remember, you are not animating you are inbetweening.**

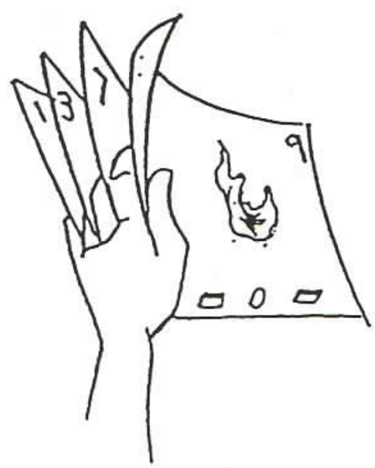
TIMING CHART

2.) ROLLING THE DRAWINGS TO PLOT THE ARCS (and a few notes on follow thru, drag, and overlap)

This is the most important part of doing your inbetween. It is called Finding and Following the Arcs. The movements of most living and unliving things follow circular paths of action called arcs. The animator charts the position of his drawings along this arc. He makes his key drawings, indicating where the inbetweens should be placed to keep the line of action on this curved path. Inbetweens done without following the arcs change the action radically, usually resulting in jerky and stilted animation. Example:



If the animator hasn't indicated the arcs you must find them yourself. To find the arcs place the extremes you are inbetweening, plus the preceding and following extremes, in sequence on the pegs. (In our example drawings 1,3,7,and 9.)



Now, by rolling the drawings in sequence the arcs in the action become evident. Note all of these circular paths by making light indications on the keys, or on your inbetween, in blue pencil.

3.) TURN ON THE BACKLIGHT & PUT THE DRAWINGS IN FLIPPING ORDER

Place the drawings on the pegs in the following order: First extreme, Last extreme, and on top your inbetween. Turn on the backlight (The flourescent light behind your animation disk).

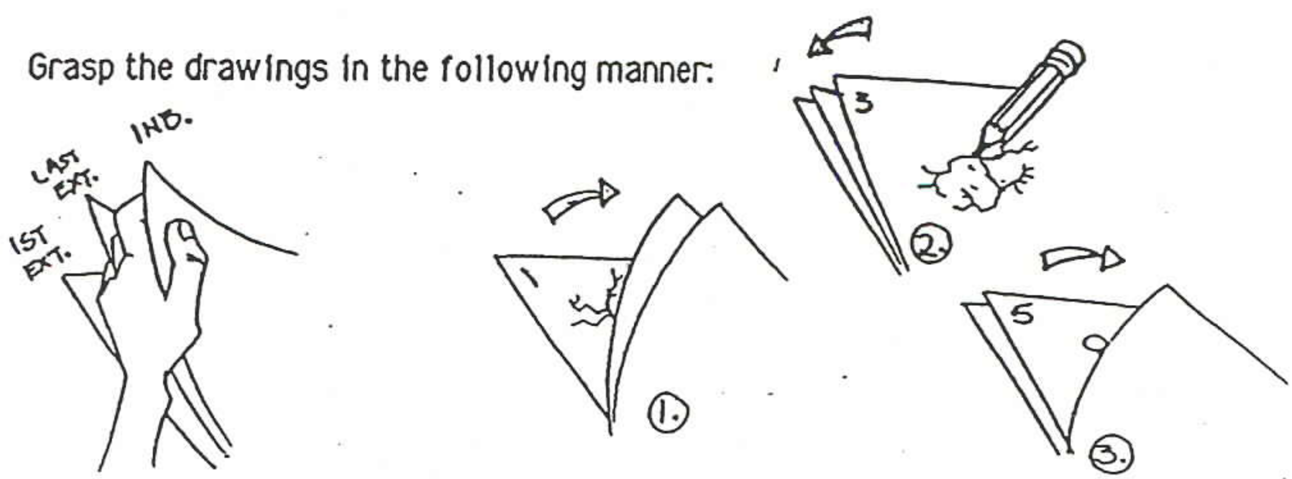
4.) BUILD THE FOUNDATION OF YOUR INBETWEEN

Now using the light, plot the position of the shapes & lines between the two keys. Make sure that you are following the arcs and are placing the shapes in the charted position. Finish drawing this skeleton for your inbetween by accurately placing the shapes between the shapes and the lines between the lines.

5.) TURN OFF THE BACKLIGHT

6.) FLIP THE DRAWINGS TO CHECK THE INBETWEEN

Grasp the drawings in the following manner:



Flip the drawings as indicated and you should be able to see the action. This is called flipping. Now flip the drawings. Does the inbetween work smoothly? Are there any lines missing? Do any of the lines jiggle or get shorter & longer? Is anything out of arc? Fix these problems then sit back and take a good look at your drawing. It probably looks pretty good to you doesn't it ? But at this point it most likely looks like an unappealing

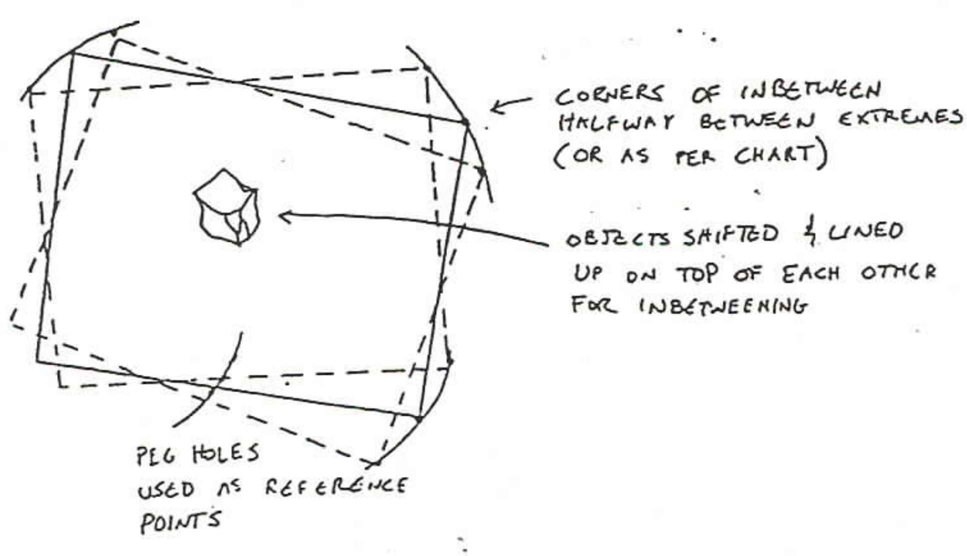
7.) ROLLING & CHECKING THE INBETWEEN

Now that you've got a good drawing that seems to inbetween properly put the drawings in rolling order. Roll through the drawings and re-check the inbetween for all the things we have been talking about, drawings out of arc, jittering & crawling lines, changing volumes, floating details and any other inbetweening problems.

8.) TURN ON THE BACKLIGHT

9.) SHIFT THE DRAWINGS OFF THE PEGS TO CHECK VOLUMES & DETAILS

Now that you've just about finished the inbetween, shift the top extreme and your inbetween off the pegs. Pick a part of the drawing you want to check. Using the light shift the top extreme until the part you are checking is lined up precisely with the corresponding part on the bottom extreme. Tape or hold the drawing in place. Next, line up the inbetween between the keys using as many reference points as possible. Now by flipping and using the light you will be able to see & fix any problems with the tiniest of details: such as volume changes, placement of details, and bobbling features to name a few. Proceed through the inbetween checking & fixing all the detail in this way. **(HINT: With 1/2 inbetweens you can often use the corners of the drawings and the peg holes to line up the drawings, see the diagram below.)**



10.) DO A FINAL CHECK OF THE INBETWEEN

Roll through and flip the drawings to do a final check of the inbetween. Fix the problems if there are any.

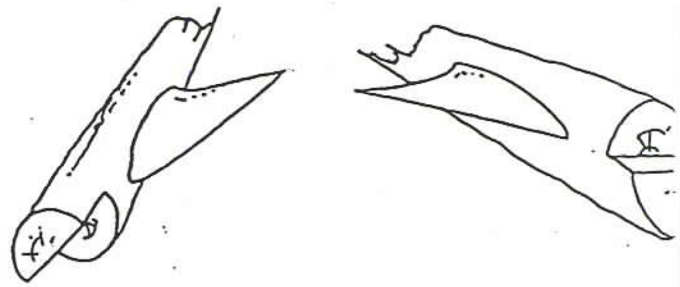
START THE NEXT INBETWEEN

After every five or six inbetweens take your drawings to your supervisor or the animator to be checked. Also if you get stuck on a drawing problem ask for help, someone experienced can usually solve your problem quickly.

USING BASIC SHAPES AS AN AID IN DIFFICULT DRAWINGS

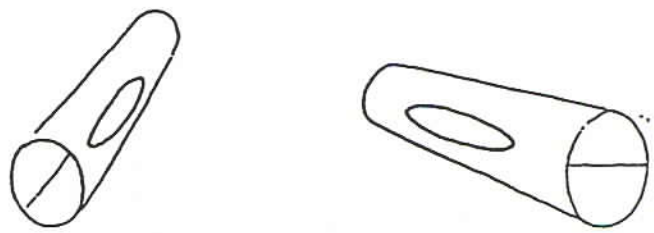
There is no substitute for good drawing, and the most logical approach is to rely on basic shapes to get that good drawing. Most of the problems that come up are when an object moves far enough so it can't be inbetweened (lines between the lines) and has to actually be drawn. All of a sudden here's a rock that has to be drawn.....FROM SCRATCH! No model! You think no rock ever got into that position before. The extremes were easy to draw, but the inbetweens are impossible.

A difficult inbetween



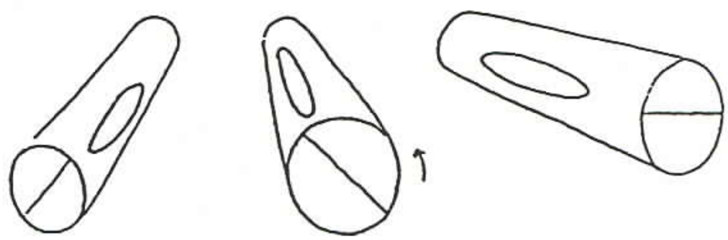
Another difficult inbetween

Find the basic shape

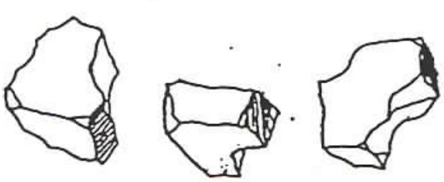


Find the basic shape

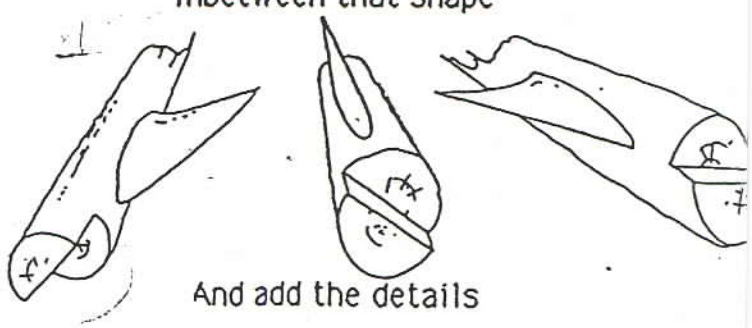
Inbetween that shape



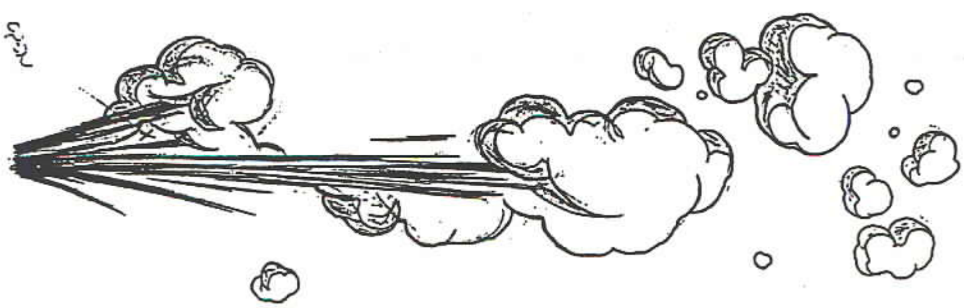
Inbetween that shape



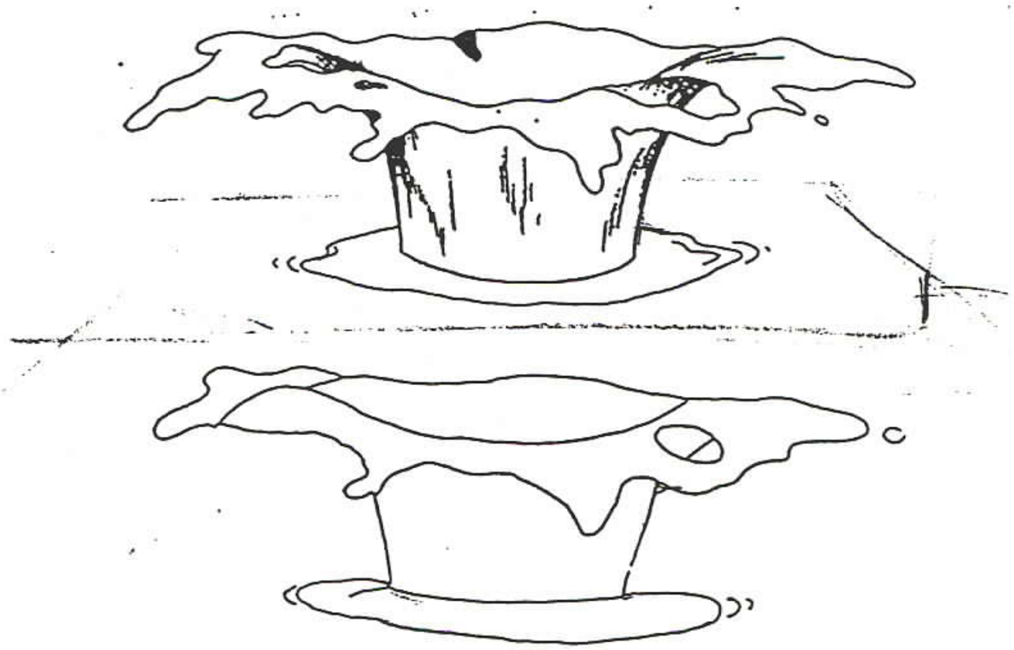
And add the details



And add the details



You must now make sure your inbetween works as a 3-Dimensional drawing. Flipping all the while, check to see that details are properly drawn in perspective and are firmly anchored to the main masses. That things look solid rather than flat, that the lines wrap around the forms. Think of the drawing as a real object and try to imagine the unseen side of the form. Sculpt as you draw.



Look closely at the extremes as you flip and see the way the forms are described. Try to match the animators drawing, and most of all try to capture that fleeting essence that will give believability to your drawing.

If your drawing looks flat or warped it is probably because it hasn't been inbetweened 3-Dimensionally. This can be overcome by building your inbetween using basic shapes such as cubes, balls, and cylinders. After laying in the basic forms it is a simple matter to add the details.
It is extremely important to construct your inbetween or the animated shapes will look like they are made of JELLO, and details will float instead of being anchored to the main masses.

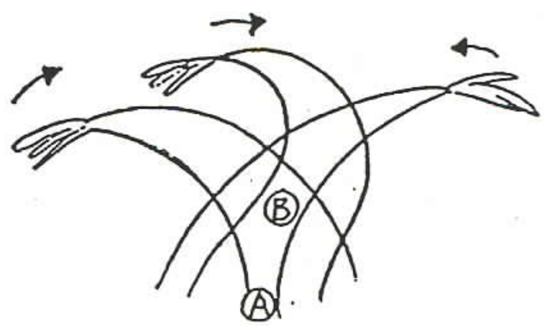
OVERLAP, FOLLOW THRU, AND DRAG

While rolling the drawings you should watch for places where the above animation principles are being employed, and be sure that your inbetween doesn't stiffen the action.

To find overlap, follow thru, and drag determine the primary action. Now anything attached, if flexible, will have an overlapping action. In other words appendages DRAG until the primary action changes direction, then when their secondary action is spent they overlap, follow thru and drag.

For example to keep things like branches, leaves, ropes, and flags soft and flexible they must drag slightly at the beginning of, or during, a move. And they must overlap at the end of a move or at a change of direction.

This principle for changing direction can be applied to anything flexible. Connection to the primary action (A.) changes direction first, followed by the middle section (B.). The tip, depending on length and flexibility continues on its course of action until interrupted by the pull of the main body (A & B). **(Hint: Study the action of a thin strip of paper.)**



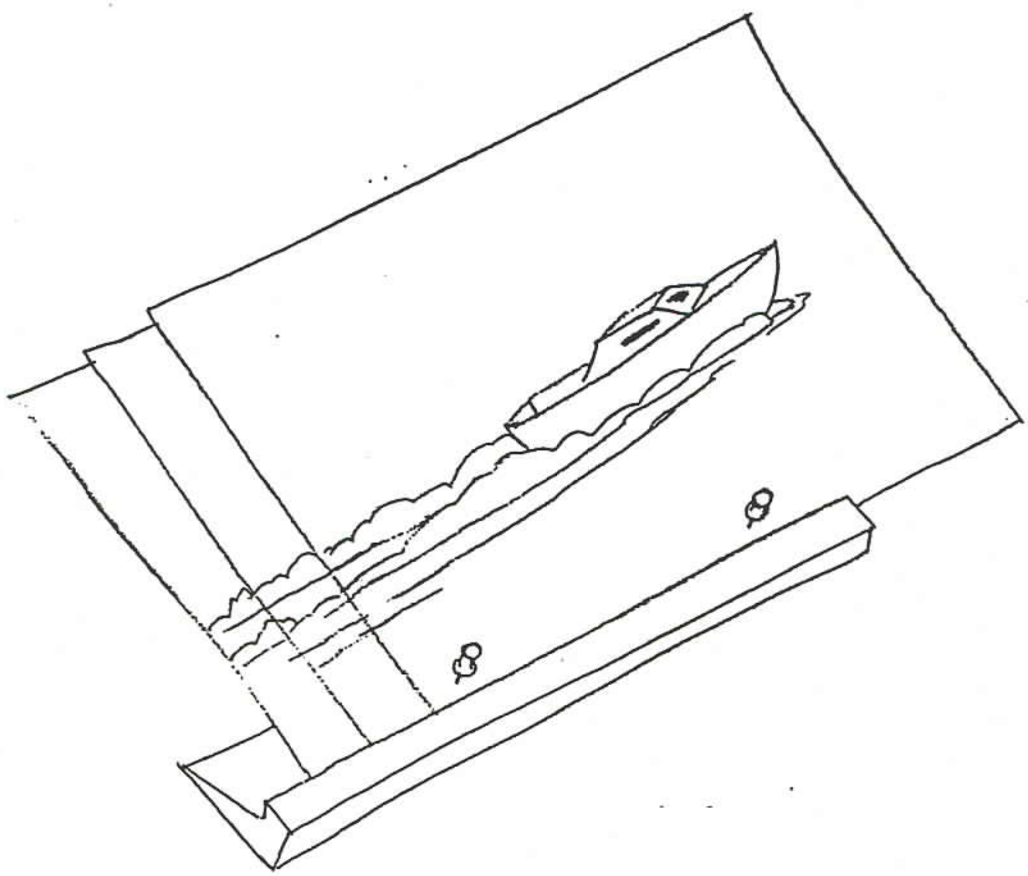
Following the animators ruffs on all drags will contribute to loose animation.

The Pan Stick

The pan stick is a wooden device. It allows you to neutralize a pan move by shifting your drawings in the opposite direction of the background pan. Push pins are used to pin the drawings in registry and hold them to the stick.

An example of this would be a scene which has a boat held in place with a background panning under it. If the background is panning left 1/2 inch per frame, we would shift each boat drawing to the right 1/2 inch measured from the last boat drawing pinned on the pan stick (measured from the edge of the paper).

By doing this the ripples and splashes from the wake of the boat can be animated "in place" and will move with the background pan when the scene is photographed.



clean up notes

artistic:

- **ALWAYS** reinforce drawings!!!
- Be certain all drawings are numbered clearly
- Drawing numbers on animators' keys are circled. **DO NOT** circle any other drawing numbers!!!
- Use your disk to your advantage. Your disk is your friend!!
- Be aware of how CAPS functions affect your clean-up
- Know how much detail to include, (or leave out)
- Maintain integrity of the animation
- Match your clean-up line to that of the Key Assistant
  - Line Weight
  - Direction
  - Character Line
- Be careful not to smudge drawings
- When erasing character line, be extremely cautious
- Mark up drawings for clarity
- Close off all lines
- Be sure line is sufficiently dark
- For complex drawings only, use cels when flipping to reduce paper damage

clean up notes

general:

- Be Organized
- Develop a system that works, and use it
- Have a clear understanding of the job at hand
- Communicate with Animator and Key Assistant at all times
- **ALWAYS** follow X-sheets!!!!
- Stay focused on your task
- Set realistic goals
- Keep a record of your work and maintain a personal reel

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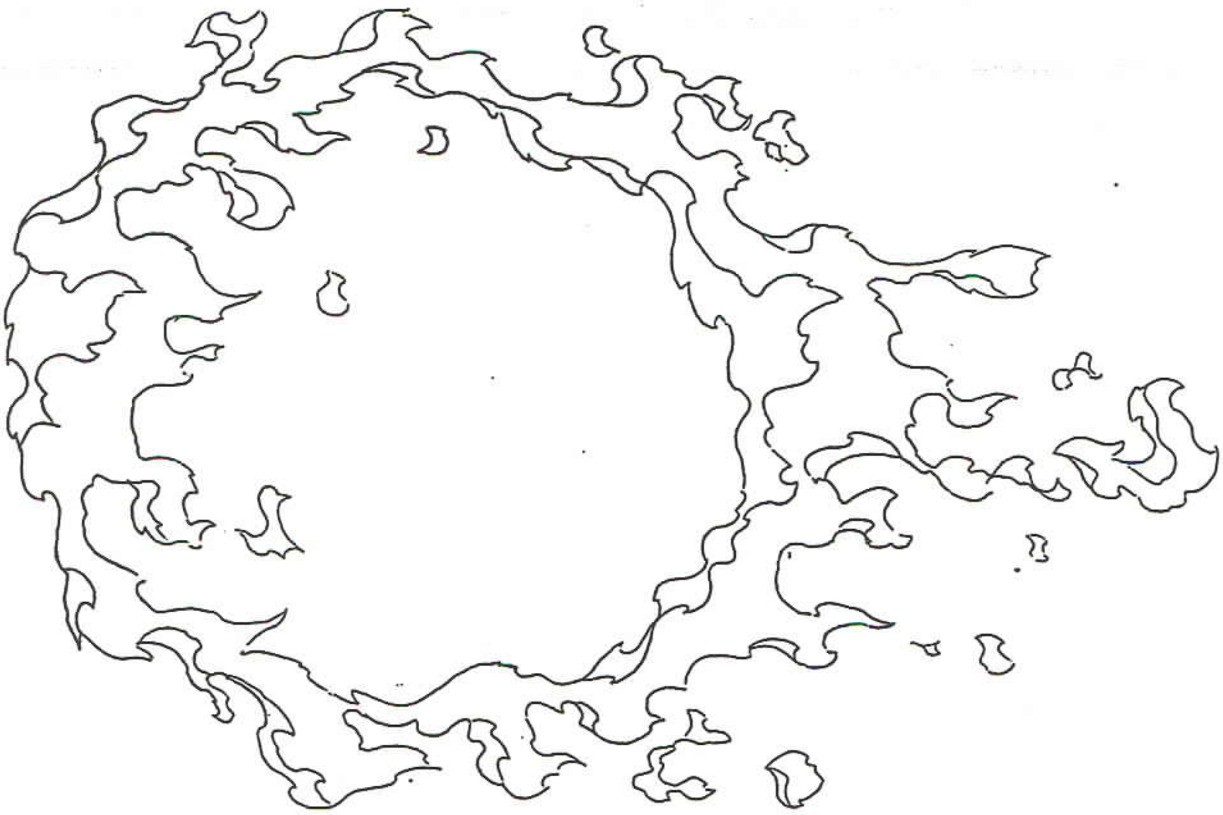

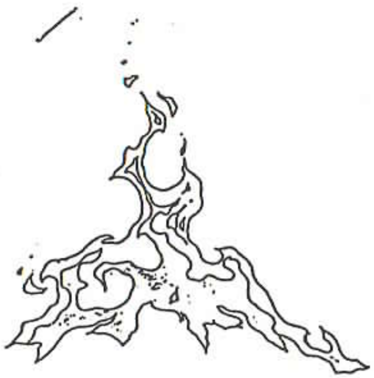

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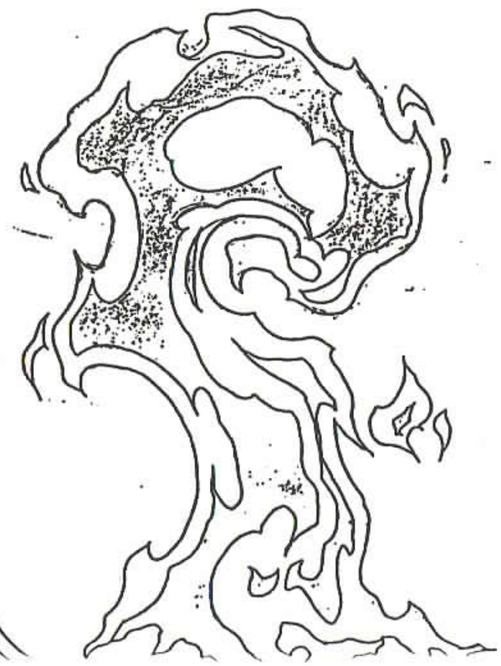
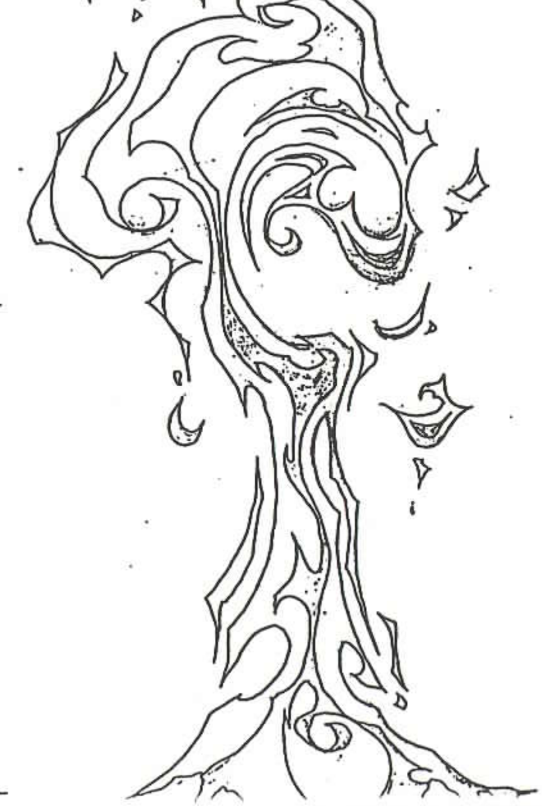
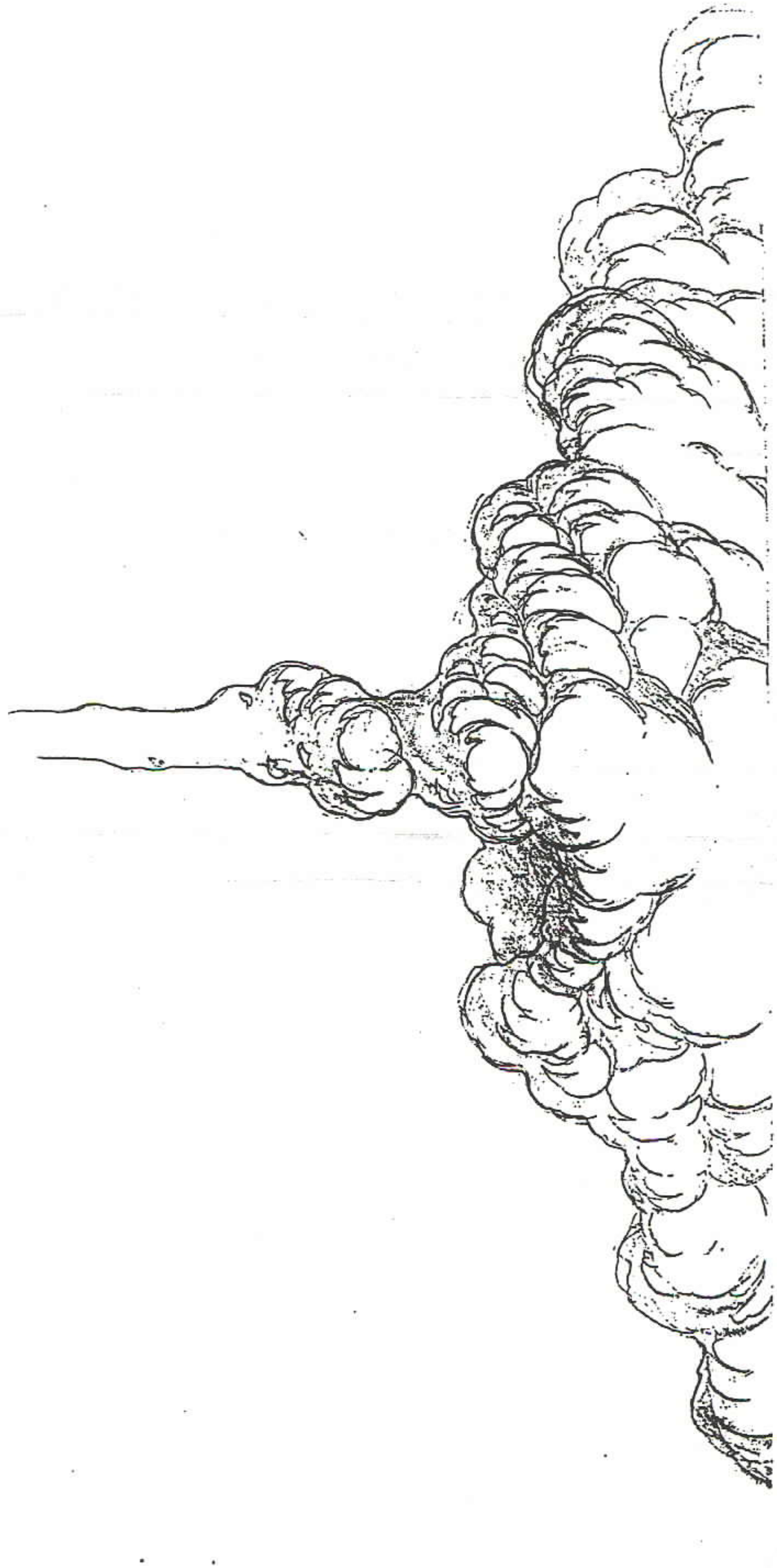
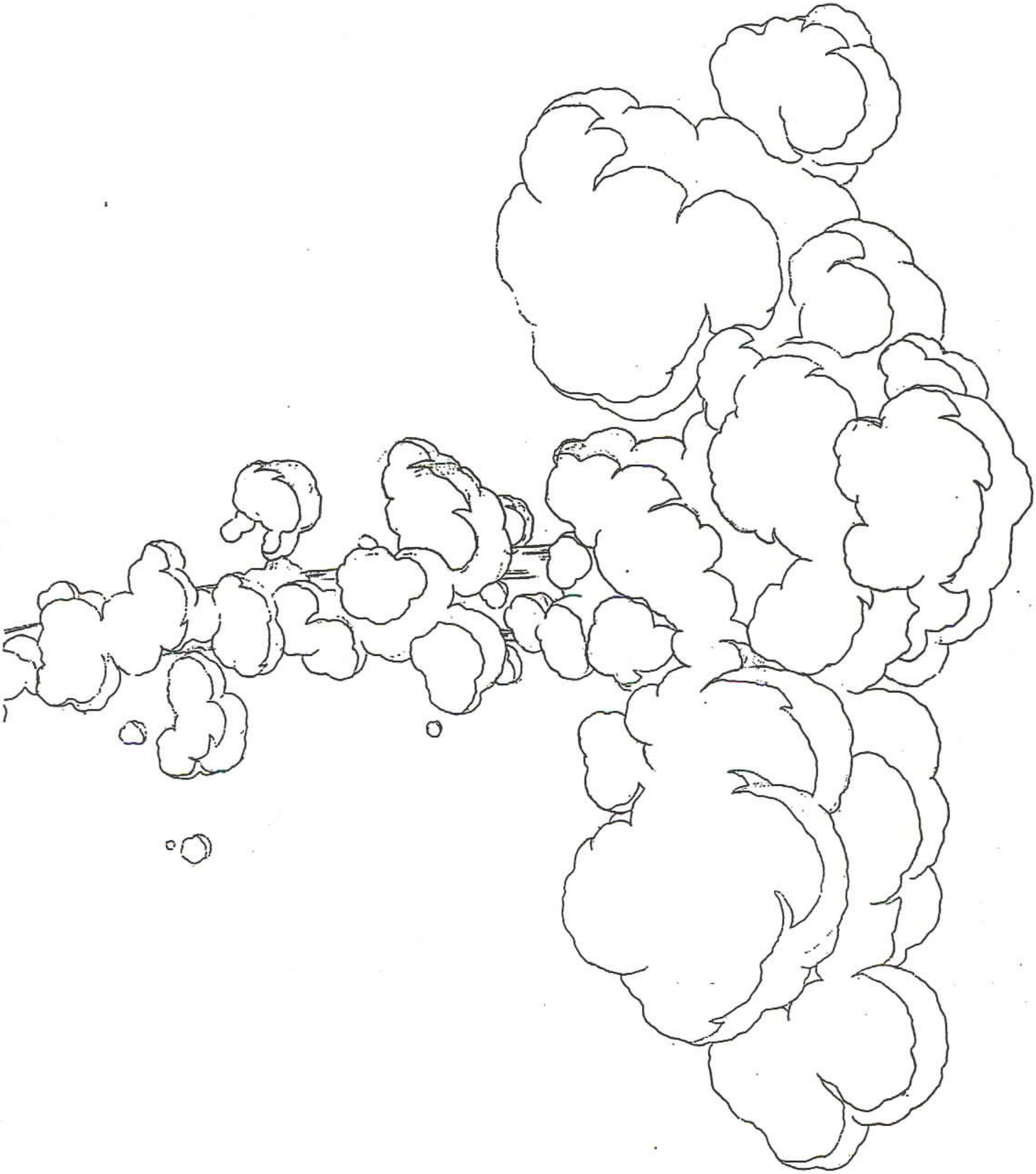
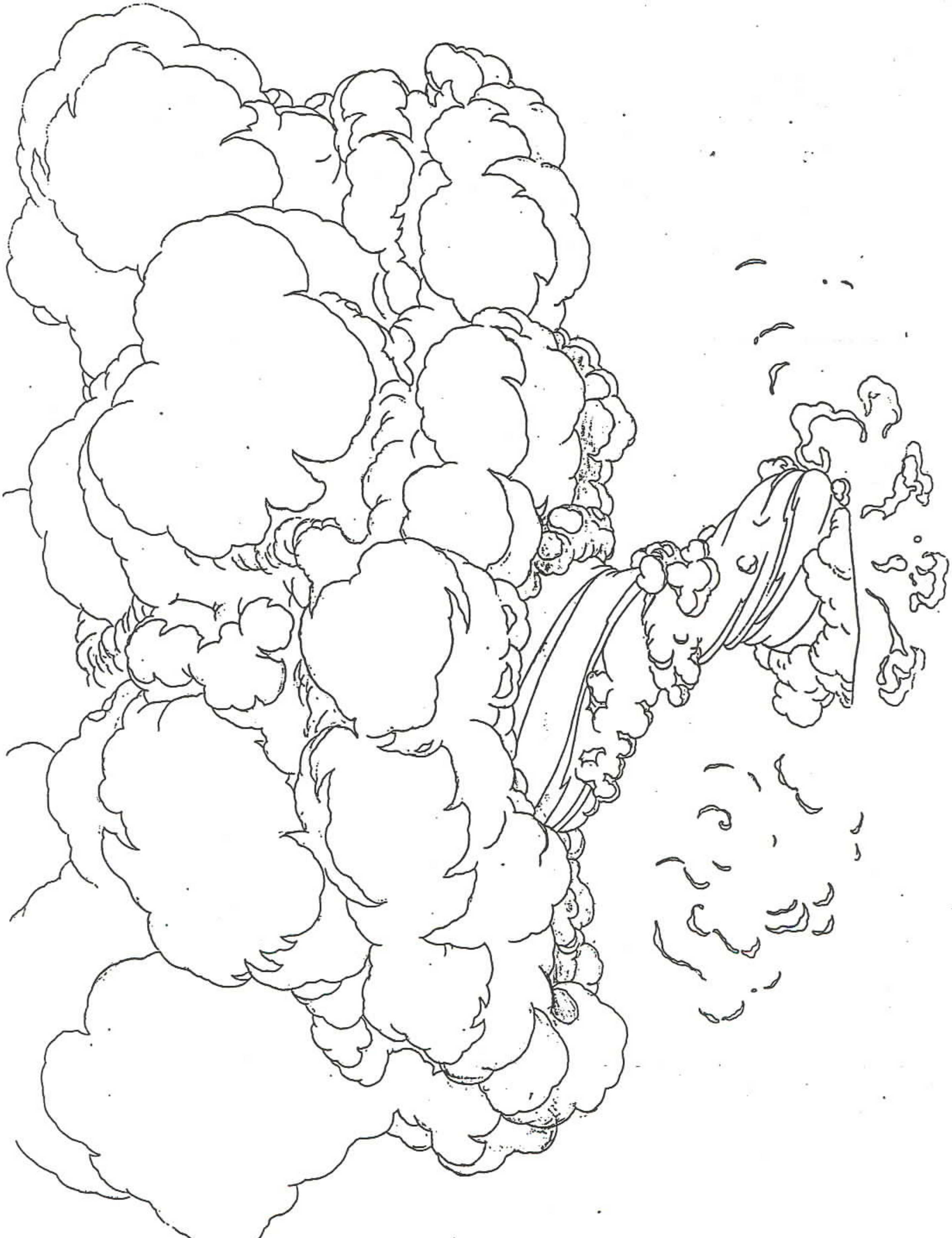










A Meditation On Breaking Waves

Out of the cradle
endlessly rocking…
The white arms
out in the breakers
tirelessly tossing,
I, with bare feet,
a child,
the wind
wafting my hair,
Listen'd
long and long.

—Walt Whitman

Waves: pulses of energy, echoes of power, children of the struggle between ocean and atmosphere, endless song of circulation. Vibrations put into motion by the harmonic resonance, the insistent music of the spheres, ocean waves are the ongoing signatures of infinity, eternity and the miraculous. They are the gifts of the invisible to the visible (energy into air into liquid), the voices of intelligent silence, the incarnation of the molecular soul in corporeal reality. As God breathed life into the raw form of Adam, so the wind breathes life into the inert ocean, raises it into a running rhythm, lifts it up out of itself and, finally, transforms the sea into the spectacular living glory of breaking waves.

There, at the meeting of land and sea, ocean waves reveal their essential meaning; deliver their messages. As spectacularly varied as snowflakes, more powerful than avalanches, as relentless as the pull of the moon or the grip of the sun, the ocean—as expressed in its breaking waves—is a limitless source of adventure, mystery and sensual richness.

We sit on the shore and watch the waves moving incessantly toward us (forever and ever throughout all lifetimes) and we marvel at their beauty and thrill to their surprises, while we're soothed (forever and ever) by their cadence. We sit marvelling on the shore, and the waves advance to meet us. They materialize out of the general abstraction of the ocean, climb into increasing definition, then feather, plunge and (ever more slowly) rush or push or crawl ashore.

In the absolute beginning, as infants in the womb, everything came to us as waves, advancing through the primal liquid to acquaint our senses with sublime echoes of an invisible world beyond the realm of our comprehension, beyond the smaller space we knew, making that familiar life of the womb by this mysterious contact somehow more infinite, somehow more momentous, poised on the brink of a greatness, an unknown significance.

So that even now, who could not sit and watch the sea and the breaking waves for hours…for days…forever? Never ending, untiring the march shoreward.

Rank upon rank of waves, leaping, curling, plunging. Each upon each, and absolutely infinite the variety. No two in all the millenia curling over exactly alike. Each one individual. Each one yet another unique expression of the complex interweavings of natural law. Each one an identity. Each part of one an identity. The inexhaustible creativity of it almost overwhelming.

Rank upon rank, echoing that invisible, all-powerful source that all form calls out from. Relentless and utterly reliable, terrible and beautiful.

No doubt men of all times have stood upon the shore and lost themselves in the thunder of the shorebreak, the cadence of the sea, harkening completely to that synchronous metre deep within the human psyche.

Or maybe not so deep. The noted oceanographer, Blair Kinsman wrote: "Phenomena do one of three things: they stand still, in which case the problem is to evaluate a constant; they grow, in which case we try to find a growth law; they oscillate, in which case we have a wave problem." So Kinsman posited a short but potent list of fundamental physical actions—mega-verbs, if you will—that give some indication of the primary importance of wave phenomena in our realities. Indeed, we are all at sea in this life, borne on an infinite network of complex oscillations. No part of our life is free of waves. We are all surfers, are we not?

Aren't we all drawn to the ocean waves? We the watchers, the voyeurs, the admirers, the seekers of that specially charged atmosphere that bathes the holy beach where ocean wave meets solid ground and gives up its accumulated life force in a powerful expression of consummation…one after another, eternally (or so it seems to us), electrifying that dynamic surf zone with charge after charge of blown energy set free to hover there.

Is it any wonder humanity flocks to the shore? We explain it in visible, tangible, sensational, reasonable ways—the cool, the water, the fun, the sun—when really it's the irresistible magnetic attraction to the energy of the place.

Yet the waves, those transient objects of our fascination, both invite and threaten. These wonders of nature are as well known for their destructive force as they are for their beauty. Ask the thousands or millions who've been consumed by the oceans and their waves. Ask them about its beauty. Ask them about its many moods.

Who would venture to guess how many millenia it took for a man to finally dare approach the ocean waves with his first rude craft? Who knows how many millenia more it took for man to actually challenge the surf, to leap on the back of the wild steed and ride until it collapsed, exhausted, up onto the shore? A long time, I'll wager. Millenia aplenty.

Unless, for instance, man's relationship with the sea and the waves was given to him—breathed into his essential consciousness by some force, some power, some other mind. Think about it: How likely is it that any conceivable evolution would have taken man down a critical path that would lead him eventually (and in our time) into the hollow pocket of a 30-foot wave…to ride in the belly of the beast…to slide through the maelstrom of a collapsing cathedral of water with the composure of a matador, with the exhilaration of a wild-haired youth, with the primitive awe of an elemental man, with the futuristic aplomb of a science-fiction comic book hero come to life, incarnate in his most bizarre predicament of all?

Picture a twister lying on its side in the ocean, pulling the water over and around itself like a ragged, raging blanket, its wider open end revealing a swirling hollowed-out cavern of spitting, hissing power, rolling like a giant tunnel toward the shore. Imagine the kind of man who'd want to put himself in the eye of this thundering killer, who—like a matador to an avalanche—would wish to stand cooly in the raging glass fist, while time grinds nearly to a halt and where the secrets of immortality are whispered to those who have ears to hear.

Perhaps it is as the German poet Rainier Maria Rilke has said, that we are "the bees of the invisible," here to harvest with our senses the realities of the physical world around us. Why? To function as the eyes and ears (and all the senses) of a being or beings that cannot directly experience this world or this reality without us. Maybe receiving and transmitting the essential knowledge of this world—more divine than we can suspect—is the central reason for our existence.

So said Rilke, and so can we ourselves ponder the imponderable questions: Why our attraction to the sea and the waves? What is the lure that seems so basic, so essential? And could it be that our play (and our crazed risk-taking) in the waves has some "larger" purpose? Is there something miraculous afoot here that we can only vaguely sense?

In fact, the surface of the sea (and its shore, and even its depths) is at the interface of several different worlds. Not different worlds philosophically, but different worlds *in reality*. Interestingly, the form of communication between these worlds is waves. The medium changes, the form and the message remain the same.

Start with the sun, worshiped through antiquity as the Great Cause of all life, now worshiped or reviled only for its observable physical effects. The sun is taken for granted as surely as our next breath.

Yet the essential relationships perceived by the

Waves, transient objects of f… fascination, both invite and threaten. Who could not sit watch for hours? Children watch from atop a World W… II bunker on Christmas Da… Photo by Bernie Baker.

ancients between our world and the sun are still as valid, still as active, still (to this day) as real. Our blindness to these relationships does not diminish them. How could it?

The sun communicates its energy—light and heat, yes, but some other basic energy of life too—through "rays," waves of influence, waves of energy, waves of communication. The rays from the sun excite and energize the atmosphere of the earth, awakening it to movement, to flow, to rhythm, to life. The wind becomes the voice of the atmosphere, but its words have come from the sun. The wind speaks the message of the sun to the sea, and the sea transmits it on through waves. The wave is the messenger, water the medium, and the message (like all messages) is energy—the energy of the sun…the energy of life.

Wind whispers the message—or shouts it or roars it—and the echo flies out through the water, expanding, aroused, relentless. At first, ripples (like voices) vibrate into life, then they overtake and merge with one another, gathering into larger waves, larger voices. More and more they overtake, join and merge together until countless ripples (like voices) have organized into massive hands of communication that radiate out and sweep across and through the vast body of the world's oceans.

Who hath desired the Sea?
—the sight of salt water unbounded—
The heave and the halt and the howl and the crash of the comber wind-hounded?

—Rudyard Kipling

It is no accident, then, that the shore has become our favorite meditative perch. No accident that the incessant rhythms of the sea calm us, bring us back into phase, reacquaint us with-ourselves. No accident that we compete with each other for an ocean view. But it's not really some "view" we're after. It's that ancient, exquisite, powerful message of the breaking waves.

I have stood on the beach on Oahu's North Shore with the ground under my bare feet shaking with the impact of giant surf on the "cloudbreak" reefs a mile or so out to sea. I stood there and watched the giants rise up out of the rugged horizon, arch up into magnificent walls (I had no way to estimate their size), then curl over in slow-motion silence to the count of one…two…three…four—so that now I had some idea of how big they were—leaving behind a somehow frightening sweep of blue-white mist that drifted back to the water like a diaphanous veil out from under which some beauty has just inexplicably vanished.

I stood there as the raging wall of blasted white water advanced on the shore with no sign of weakness or slowing, a wall of white water so huge that the new giants farther to sea could barely be seen fringing above. And then the white water, driven ever forward by too much force, by force uncontainable, was absorbed back into the ocean itself, as the giant wave steadily and ominously began to reform closer to shore, growing larger and larger as it began to loom closer to the reef and the sand banks just off shore.

I stood there at the high edge of where the last giant had lately smoothed the golden sands, looking down a long, steady slope to the churning mass of the sea. I knew there was nothing to stop the great momentum that was to come, yet I could not move. I didn't want to. The words in my head urged retreat, but the great wave—now arched like a cobra over the inside reef, beginning to curl over in a twisted, muscular mass of storm-brown water—absolutely compelled my attention. So I stood and watched it torque and grind and explode into another seething wall of angry white water (though its whiteness was not of any particular purity; it was a whiteness by contrast) and then it was closing on the shore, first draining, then swelling the ocean's rim, until finally it drove up the beach toward me in the form of a powerful, sweeping surge. I had never seen white water come up the beach so fast.

It was a broad beach—maybe a hundred yards—but the wave covered it in three or four seconds…and still I could not move. I stood there with my legs apart, and the water surged up the beach and around me and past me; the sensation of the racing water around my legs was powerful and exhilarating.

The water rocked me, but it didn't topple me. It was then that I turned and saw how it had run up over the ledge to the house behind, running under it, encircling it. The trick, in the wave's retreat, was to keep out of the way of the things that it was taking back to sea with it—coconuts, a lawn chair, a volley-ball, a surfboard (which I managed to retrieve). And then the wave was gone, the area around me hissing with dying foam, and the sweep of golden sand down to the water's edge was washed clean.

Other times, I've stood on that same shore, looking through binoculars a half-mile down the beach into the curling tube of the famous Banzai Pipeline wave, watching from a clinical distance the wrenching suddenness with which the massive ground swells heaved high over the coral reef…watching the racing wall of water go completely vertical, then throw out a six-foot-thick lip from the top that pulled the wave into a cylinder big enough to surround a semi-truck. I've watched surfers slide deftly over the teetering cornices of waves like that, slide right down the face on the ragged edge of control, then take aim and come flying down the barrel toward me. Most are shot out alive.

I've stood on the beach in Western Australia and watched the waves there, remarking to myself that the different water of the different oceans makes the waves somehow different. Different in more than just water color or power—more a difference in quality. And the surfers there guard their waves jealously and ask you where you're from and if they can please have the roll of exposed film from your camera.

I've watched monster standing waves off Portland Bill in the English Channel, where strong currents and strong winds in direct opposition create a wild, nightmarish seascape that you have to watch from shore to truly appreciate…and be able to tell about later. These are the kinds of seas that spawn true lore. At times the local folk have stood on the low cliffs above the raging sea like spectators in a gallery, watching boats going down with all hands.

Off Lighthouse Point in Santa Cruz, California, I've seen a tremendous stack of smoking hump-backed peaks looming up out at the second and third reefs of Steamer Lane, back-lit to an almost incandescent green by the late afternoon sun. I've seen seals wriggle into the fall lines of these beauties and catch a free ride into the cove with all the apparent glee of any other surfer on the planet.

I've watched big, savage tubes uncoiling right along the rim of a reef planted with razor-sharp red fire coral in Guam, with surfers slotted back in the barrel, walking a fine line with disaster. Even so, they can't resist the lure. They do it every day.

And many an afternoon I played in the waves at Makaha on the leeward shore of Oahu, where perfect four- or five-foot waves would peel off along the reef toward the big bowl of steep beach. And then the reflection of a wave that went before would rush out to meet the one approaching and, like sumo wrestlers colliding belly to belly with a wild slap, a fan of transparent water would be flung up across the setting sun.

I've spent many a late afternoon afloat on a surfboard, lying or sitting on it out where the waves form, waiting for a good "set" to come through with a perfect wave to end the perfect day.

It's a great feeling out there with the waves, especially on those days when the swell is clean and the sea is glassy and the fiery colors of the dying sunset burnish the world around you with golds and oranges and purples.

And then a dark line lifts up out of the ocean seaward and a wave moves silently toward you—a wave that has come five hundred or five thousand miles—and you turn your board toward shore and drive your hands alternately into the cool water, gathering speed till the wave starts to lift you…lift you…and then you're sliding down the smooth face, turning ahead of the curling peak to speed across the hollowing wall. The feelings and sensations created are euphorically beyond words.

This is how I explain the ocean and its waves to my two-year-old daughter: This is the ocean water. This is where the fish lives, where the shark hunts and the whale plays. Those are waves of water—one and another and another and another and another. More and more. On and on. Like a clock. Like time. Beautiful ocean water…beautiful waves… beautiful time.

And this is how I explain the ocean and its waves to my five-year-old son: This is the ocean. It's the biggest part of nature that we can get to that's still alive. We have to try very hard to keep it alive. And these ocean waves are perhaps the most incredible things on the planet. I used to lie on the beach and watch them for hours and hours at a time. I have never gotten tired of watching them. It's almost as if they're trying to tell me something. Or that they *are* telling me something, and I'm trying hard to *hear* it. You've probably noticed how much I like to surf or bodysurf in the waves; it makes me realize that I'm alive in a very strange and wonderful world because nothing in this world is more wonderful or more strange than waves. I hope we'll be able to play in them and ride them together when you learn how to swim, which I hope will be very soon.

And this is how I explain them to myself: Everything is waves. The universe of space and matter is charged with energy, and this energy is organized by God or by forces far greater than ouselves into the pulsations we call waves. Waves of energy. Like echoes of the heartbeat of the absolute being, waves give expression to the divine will. They give form to the universe.

The passage of energy through matter organizes matter, and waves pass through everything—steel, stone, flesh and blood and water and air and space alike. Waves are the imprint, the signature, not only of life, but of existence itself.

Waves penetrate, pass through and shape everything, but the medium is not the message. Space, air, water, blood, flesh, stone and steel are not the messages. The messages are what is contained in each wave, and the message is energy.

Light waves emanate out of the sun and the stars and their reflections (like satellites or fire or electrical spark or glowing minerals or luminous fish and bugs). Seismic waves move through solids, liquids or gases. Out on the surface of the ocean, it is the movement of the atmosphere, the wind, rubbing against the water that feathers the surface, that coaxes the ripples into their gentle side-by-side expansion, then forces wavelet upon wavelet till they gather, amplify, swell and expand into giants that seem to groan with potential power as they sweep out across the great plain of the ocean, running free as if nothing could ever stop them. Until, surprisingly, they trip over some buried coral reef, lurch forward and take the fatal fall—that fall that thrills our eyes and electrifies our senses—upon that net of beaches which, from the beginning, was fated to trap the potential of every wave that's created.

Once upon a time, in Utah of all places, the whole tale was revealed to me in a 200-yard-long, shallow strip of water alongside the Interstate. There was a solid 40-knot wind blowing straight out of the north, right down the length of this small pond, if you could call it a pond, since it was actually nothing more than the traces of a Caterpillar D-8 or some other heavy machine that had lowered its blade to excavate this shallow, purposeless cut which had since become pleasantly bordered in meadow grasses and filled to the brim with rainwater.

On this particular day the sky was magnificent, blown clear and dry by the wind, and the water in this strip of pond was as deep and rich and thick a blue as a wet smear of fresh aquamarine oil paint. But the wind told a grand tale on that minute parcel of water.

At the north edge of the pond, the winds swept the grass bendingly out over the glassy, green-blue, mirror-smooth surface. The reflection of the grass, the sky, the occasional cloud there was near to perfect. You could see, then, a foot or two out where the atmosphere—the wind—was having its first effect. There was the slightest suggestion of distortion at first, a nuance of texture, almost a mirage you might have thought, except immediately after there came a deepening suggestion, an affirmation of the movement, a tendency to a pattern that somehow suggested an approaching chaos. Yes, energy threatening established order, swinging reality toward some new and unseen balance…nature resolving its differences in the only lawful way possible.

Then the pattern deepened as thrilling texture became eloquent rippling, and the yang front sides of the advancing microwaves went almost jet blue-black, chased (each one) by its yin half toward oblivion. For there was an oblivion swiftly approaching as latter ripple overtook former ripple (how it happened, I don't know) and in the overtaking both were enlarged. And then that ripple overtook another slower ripple…redoubling, redoubling…until at some dizzying height around three inches their crests began to rip apart, bursting into blossoms of white, chasing across this diminutive pond like creatures with their hair blowing, leaping forward—still pushed from behind by that steady, strong 40 knots, yet somehow chasing ahead now on their own, caught up in a stampede, a momentum of some passion, some joy (I sensed), some passion to arrive. But where?

Ah, yes. The waves—because they were really waves by now, five or six inches high, clearly delineated, formed, individual and relatively powerful—sensed the approach of the opposite shore…the bottom gradually shoaling (where the D-8 had sculpted its first slice into the soil), forcing the energy up, pushing the wave up out of itself, creating feathering, fringing lines of surf that rose, hollowed, folded and spilled up onto the distant beach a lifetime away from the other side. One after another, each after each. All different, and all the same. The waves were born, they lived and they died. Lives on the pond.

And still the wind rubbed its cool body across the water—lured, stroked, gathered and chased the surface into waves—precisely akin to the process far out to sea, far beyond the reach of our straining eyes, where the waves that finally dissolve away at our feet were born. But how?

Reflections in a boat-wal wave in the channel betw the Hawaiian Islands of and Maui. Photos by Job Severson.

THE LIFECYCLE OF OCEAN WAVES

Under heaven
nothing is more soft
and yielding than
water.

Yet for attacking the
solid and strong,
nothing is better;

It has no equal.

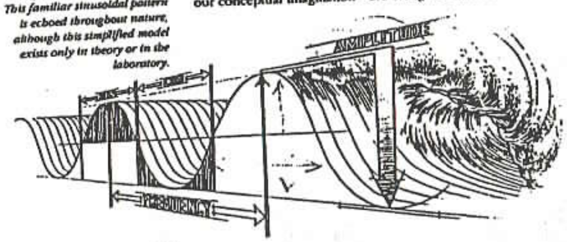
—Lao Tsu

We are surrounded and influenced everywhere by waves. From the radiations of light and color, to the sounds that vibrate through our atmosphere, to the cycles of the tides, and of night and day, and of the movements of our lives—it seems that everything comes in waves, or as cycles moving within waves.

Clearly, wave action is the fundamental way in which energy is transported and transmitted in this world. Waves are an expression of the universal rhythm that orchestrates and propels all creation and the development of life on earth. Perhaps this is why the contemplation and study of ocean waves is so attractive, so compelling.

Ocean waves are among the earth's most complicated natural phenomena, yet when we picture waves in the abstract, our minds might conjure an image of the perfect concentric ripples that echo the point of entry of a pebble into smooth pond waters. Those waves—the ideal waves of our conceptual imagination—are elongated sinusoidal oscillations *[Fig. 1]*, and although they do exist in relatively pure form in controlled conditions, they are not likely to be found in the more complex ocean environment *[Fig 2]*. This is why waves are usually studied in laboratory tanks, where a single train of waves can be generated and where the mechanics of wave motion can be isolated and simplified.

Figure 1—An ideal wave: This familiar sinusoidal pattern is echoed throughout nature, although this simplified model exists only in theory or in the laboratory.



Ocean waves and laboratory waves share the same basic features: a crest (the highest point of the wave), a trough (the lowest point), a height (the vertical distance from the trough to the crest), a wave length (the horizontal distance between two wave crests, and a period (the time it takes for a wave crest to travel one wave length) *[Fig 3]*.

Standing on a pier or jetty, or sitting astride a surfboard, the swift approach of an ocean wave gives the impression of a wall of water moving in your direction. In actuality, although the wave is moving toward you, the water is not. If the water were moving with the wave, the ocean and everything on it would be racing into the shore with catastrophic results. Instead, the wave moves through the water, leaving the water about where it was.

Spread a blanket on the floor. Kneel at one end and take the edge of the blanket in your hands, then slowly snap waves down its length. The blanket doesn't move, the waves ripple through it. The energy crosses the blanket in an oscillating wave pattern, diminishing (or decaying) as it moves toward the opposite end.

An ocean wave passing through deep water causes a particle on the surface to move in a roughly circular orbit, drawing the particle first toward the advancing wave, then up into the wave, then forward with it, then—as the wave leaves the particle behind—back to its starting point *[Fig. 4]*.

Because the speed is greater at the top of the orbit than at the bottom, the particle is not returned exactly to its original position after the passing of a wave, but has moved slightly in the direction of the wave motion.

The radius of this circular orbit decreases with depth. In shallower water the orbits become increasingly elliptical until, in very shallow water—at a beach—the vertical motion disappears almost completely.

Its final destruction in shallow water culminates the three phases in the life of a wave. From birth to maturity to death, a wave is subject to the same laws as any other "living" thing, and—like other living things—each wave assumes for a time a miraculous individuality that, in the end, is reabsorbed into the great ocean of life.

The Origins of Waves

Undulating ocean surface waves are primarily generated by three natural causes: wind, seismic disturbances and the gravitational pull of the moon and the sun. Oceanographers call all three "gravity" waves, since once they have been generated gravity is the force that drives them in an attempt to restore the ocean surface to a flat plain.

There are other waves, too, in the ocean. At the boundaries of cold and warm currents, submarine streams of different density undulate past each other in slow-moving "internal" waves. The evidence of internal waves can sometimes be seen in calm conditions since their currents affect the reflectivity of the ocean's surface, producing alternating areas of glassy slickness and ruffled texture.

Although significant seismic-wave disturbances (tsunamis) are still popularly known as "tidal waves," the term more accurately describes the daily cycles of high and low tides. The greatest ocean waves of all—with a period of 12 hours and 25 minutes and a wave length of half the circumference of the earth—these colossal oceanic bulges travel around the world at up to 700 or 800 miles per hour. The tides are created when the massive gravitational pulls of the moon and the sun actually lift the oceans while the earth rotates by underneath. The crests of these waves are the high tides, the troughs low tides.

One unusual tidal wave phenomenon is a "bore," the sudden surge with which the incoming tide arrives in some parts of the world. Bores occur in streams or rivers (like Britain's Severn River) or bays (like the Bay of Fundy in Nova Scotia) with funnel-shaped shores and shoaling bottoms where tidal ranges are high. If the incoming tide is retarded by friction in the shallowing water until it moves more slowly than the outgoing current, the tidal surge can build up into a turbulent crest. The resulting bore wave may drive up a narrowing passage with great energy and force.

Augmented by a west wind and spring tides, the bore on France's river Seine (called the mascaret) has been known to arrive at Paris as a great wall of water moving at high speed. One report claims a 24-foot-high wall of water traveling 15 miles per hour. This is the tidal bore that drowned Victor Hugo's newly married daughter and her husband, who were caught while sailing on the river in front of Hugo's home.

The other "tidal waves"—seismic sea waves, or tsunamis—are "impulsively generated" waves, most commonly by earthquakes, volcanic eruptions or massive underwater landslides. The waves created by such abrupt forces can be very long and low with periods between crests of up to ten minutes and wave lengths as long as 150 miles. Yet the waves are usually only a foot or two high in deep ocean water, and the slope of a tsunami wave face can be so gradual that ships at sea are unlikely to even notice its passage.

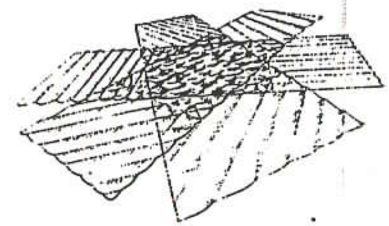


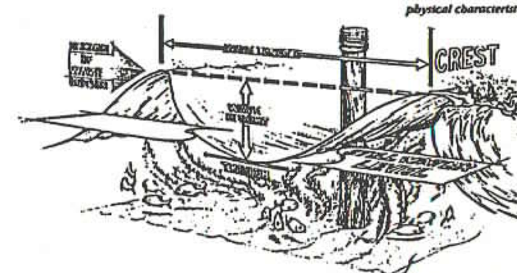
Figure 2—The surface of the sea: The interaction of many simple sine wave patterns creates a sea.

Tsunami waves travel extremely fast—about 500 miles per hour in the mid-Pacific—and the energy they transmit can be massive indeed. But as stealthy and swift as they are through the ocean, these seismic waves assume a completely different character when they encounter a shoaling bottom.

The most notable example of the destructive power of an explosively-generated tsunami is the volcanic eruption in 1883 of the northern portion of Krakatoa, an island located in the Sunda Strait between Java and Sumatra. Some five cubic miles of lava, pumice and ash were blown out in a massive and sudden eruption, leaving a 900-foot-deep crater where a 700-foot-high land mass had been. The blast was heard in Madagascar 3,000 miles away. Although immense physical destruction was caused by the explosion, the real catastrophe was caused by the resulting tsunami, which ranged from 60 to 120 feet high. Some 300 towns and villages on the shores of nearby islands were destroyed; over 36,000 people were killed. The gunboat *Berouw*, anchored off Sumatra, was carried nearly two miles inland, and gauges in France and Britain recorded a rise in the sea level.

In 1960, a violent earthquake in Chile (magnitude 8.5) caused a great subsidence of the undersea fault that parallels the coast there, generating a catastrophic tsunami that affected nearly all of the Pacific basin. Australia, New Zealand,

Figure 3—The anatomy of an ocean wave: Whatever the medium they move through, all waves share the same basic physical characteristics.



The Lifecycle of Ocean Waves

Genesis: Winds blowing across the water's surface raise ripples, then chop. If wind strength, duration and fetch are sufficient, a "sea" develops.

Fetch: The area over which the wind blows to raise up waves; most (but not all) of the atmospheric energy transferred to the water by frictional forces is concentrated at or near the surface.

Maturity: Once the seas leave the fetch area, the locally confused patterns organize themselves into lines of swell that radiate downwind from the area of genesis.

Particle movement: Waves passing through water cause particles near the surface to move in circular orbits. The diameters of these orbits diminish at depth increases.

Landfall: As swells begin to be affected by a shoaling bottom, their character begins to change; they begin to slow, the wave length shortens and, when the bottom is shallow enough, they break.

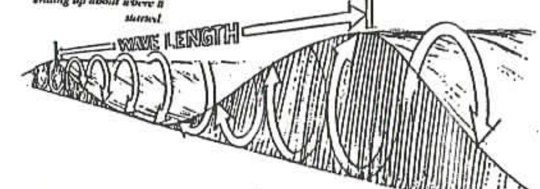
Breaking waves: When a shoaling bottom causes waves to become critically steep, they peak up and break; the shallow water no longer allows the complete internal rotation of the water particles.

Final moments: The momentum of the plunging breakers pushes water toward the shore, expending the last of the wave energy.

the Philippines, Okinawa and California experienced significant coastal flooding or damage. Fifteen-foot waves were hurled against Japan, some 9,000 miles from Chile, and the city of Hilo on the Island of Hawaii (which had been devastated by a tremendous tsunami as recently as April 1, 1946) was virtually washed away by a series of massive seismic sea waves that began to hit less than three hours after the quake. Hilo has since been rebuilt on higher ground, dedicating the former site—now called "Tsunami Park"—for recreational use.

Although tsunamis are certainly spectacular if you're in the right place at the wrong time, they are relatively rare. And the tides (although they're always with us) are relatively slow to shift and difficult to observe as waves. On a day-to-day basis, wind-generated waves are the most visible to us. Ripples, chop, rough seas or plunging breakers, these are

Figure 4—How particles are moved by waves: An individual molecule of water is displaced in a circular pattern by the passage of a wave, ending up about where it started.



what we think of when we hear the word "waves," and their source is the movement of air across water.

Wind is the result of solar energy acting on the earth's atmosphere. The great patterns of circulation—the global winds—give rise to the various dynamics of high and low pressure, of calm and storm. Huge North Pacific or North Atlantic or Antarctic systems generate enormous waves. More localized thermal differentials excite the ocean's surface with racing patterns of energy. Smooth coastal waters oscillate gently with the decaying echoes of storms half a world away.

How does the wind make waves? The primary mechanism of wave genesis is the friction between the atmosphere and the surface of the ocean. A puff of less than two knots will raise miniscule wrinkles (called capillary waves) on the surface almost immediately. As the puff dies, these waves quickly disappear due to the resistance of the water's surface tension, which tends to restore the smooth surface. However, when a breeze of two knots or more develops and is sustained for a time, "gravity waves" begin to form as the wind drags across the water. Ripples at first, these waves continue to grow as the wind continues to blow. In fact, it becomes increasingly easy for the wind to transfer its energy to the water since it can now push directly against the backs of the ripples. The more jagged and uneven the surface, the more there is for the wind to push against. Ripples develop into chop (periods of one to four seconds) until, when the wave length of the chop in a given area stretches beyond five seconds or so, it is called "sea" *(Fig. 5)*.

As the waves continue to grow, the surface resisting the wind becomes steeper and higher, making the wind's work of transferring energy to the water still more efficient. But there is a limit to how large these waves can grow. Steepness is a ratio of the height of a wave to its length which, it turns out, can't exceed approximately 1:7. This means that a seven-foot-long wave can't have a crest taller than a foot. In fact, the maximum stable profile angle of a wave crest is about 120 degrees. Beyond this point the wave will begin to break into whitecaps.

How large wind waves become is a function of three factors: the strength of the wind (force), the length of time it blows (duration), and the amount of open water over which it blows (the fetch). If the wind is strong enough and blows long enough, waves of considerable size can develop. However, there is a limit to the amount of energy that can be transferred from the atmosphere to the ocean for a given wind strength, and when that limit has been reached, the seas are said to be fully developed or fully aroused. For instance, an accepted mathematical model suggests that if the wind blows at a velocity of 30 knots over a fetch of some 280 nautical miles for at least 23 hours, a fully-arisen sea will be the result, with average waves of 13 feet and the highest waves approaching 30 feet.

Waves generated by the kinds of storms that actually happen seldom need fetches of more than 600 to 700 nautical miles to reach full height. According to oceanographer Blair Kinsman, 900 nautical miles is probably room enough to develop the largest storm waves that have ever been reliably estimated. Occasional open-ocean waves of 40 to 50 feet do occur, he says, but they are not common, and even in the worst storms the run is much smaller.

Kinsman developed an estimate for the "whole ocean" based on a frequency study for wave heights (over 40 thousand extracts) developed by Bigelow and Edmondson in 1947, which seems reasonable:

Wave height	0-3'	3'-4'	4'-7'	7'-12'	12'-20'	over 20
Frequency of occurrence	20%	25%	20%	15%	10%	10%

This would indicate that 45 percent of all ocean waves are less than 4 feet high, and 80 percent are less than 12 feet high. Just 10 percent are over 20 feet. The largest wave ever reliably reported had an estimated height of 112 feet. It was encountered on 7 February 1933, during a long stretch of stormy weather, by the *U.S.S. Ramapo* in the North Pacific.

In all their immense variety, waves give texture, motion and character to the world's seas. Having been aroused by the wind and gathered into radiating bands of energy, waves can travel great distances, carrying nearly intact their messages from the sun.

Maturity

Once a pattern of waves radiates free of the winds that created it, the confused chaos of apparently random sea organizes itself into even lines of "swell." The original wind waves decay, and their energy is consolidated into waves of greater length and increasing speed.

As waves increase in height, wave length also increases. In fact, even after wave height has stabilized, the lengths

may continue to increase. As a rule, a ten-second period is the dividing line between sea and swell, although there is naturally some overlap. Sea is shorter in wave length, steeper, more jagged and more confused than swell. Like those ripples in the puddle, the crests of open-ocean swell are more rounded and regular, having absorbed the energies of many decaying wave oscillations into relatively unified and orderly packages capable of traveling great distances.

Swell moves across the open ocean in trains of waves of similar period that radiate downwind from a wind source. Responding to the downward force of gravity, the lines of swell spread their forms, lose some height and distribute some of their energy sideways, lengthening the wave front as they expand away from their source. The process is called maturing.

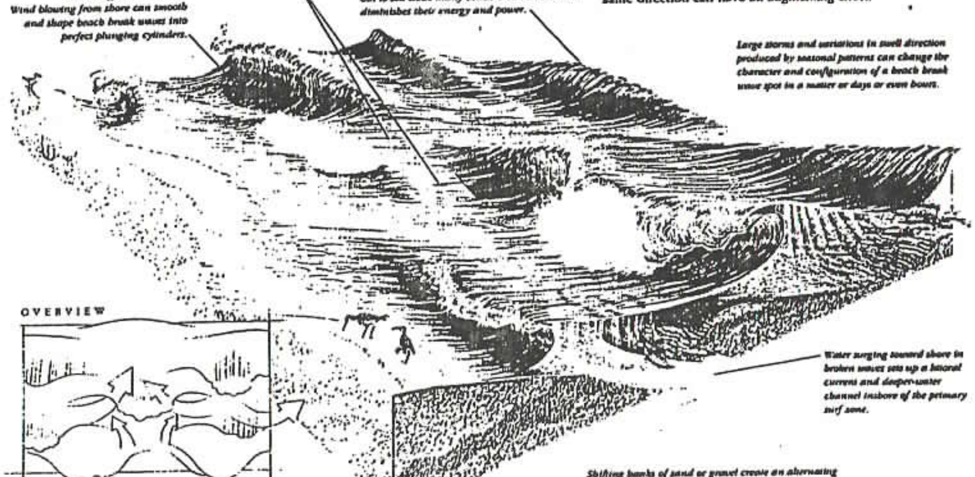
Most open-ocean waves are deep-water waves. This means that the depth of the water the waves are traveling in is greater than half the distance between crests (the wave length). Waves moving in water shallower than half their wave length are known as shallow-water waves. The wave lengths of some seismic waves (generated by earthquakes, for instance) are so long that for them even the deepest ocean is shallow. The dynamics of shallow-water waves are affected by the ocean's bottom, whereas deep-water waves can be studied independent of this influence.

In deep water, the wave length (L) in feet can theoretically be related to the period (P) in seconds by the formula: $L = 5.12P^2$. Actual wave length has been found to be somewhat less than this for swell and about two-thirds the value for sea. When waves leave the generating area and continue to move on as free waves, the wave length and period continue to increase while the height decreases. Speed also increases as period increases and is virtually independent of wave height and steepness *[Fig 6]*.

This theoretical description of the relationship between wave speed, wave length and wave period describes deep-water waves only. The relationhip between these characteristics in shallow or shoaling water can be quite different.

Storm waves in the North Atlantic average about 500 feet long; in the North Pacific they may be a bit longer. In the Antarctic waves spawned in the Roaring Forties can have wave lengths greater than 1,000 feet. Lines of swell can have much greater wave length than waves in sea. Kinsman reports swell with lengths of 1,320 feet in the Bay of Biscay, 2,549 feet on the south coast of England, and, the longest on record, 2,719 feet in the equatorial Atlantic. Where fetches are more restricted, wave lengths are naturally smaller. The longest wave length recorded in the Mediterranean Sea, for example, was 328 feet.

Under favorable conditions, swells move indefinitely in the direction of the originating wind. However, if a swell encounters new winds, the shape and heading of the waves may be altered. A strong enough opposing wind can dissipate the waves entirely, while wind or swell moving in the same direction can have an augmenting effect.



Beach Break Wave
Hossegor, France

Wind blowing from shore can smooth and shape beach break waves into perfect plunging cylinders.

Surging water pushed toward the beach escapes seaward through deeper-water channels.

The presence of a continental shelf some miles out to sea slows many beach break waves and diminishes their energy and power.

Large storms and variations in swell direction produced by seasonal patterns can change the character and configuration of a beach break wave spot in a matter of days or even hours.

Water surging toward shore in broken waves sets up a lateral current and deeper-water channel inshore of the primary surf zone.

Shifting banks of sand or gravel create an alternating pattern of breaking waves and open channels.

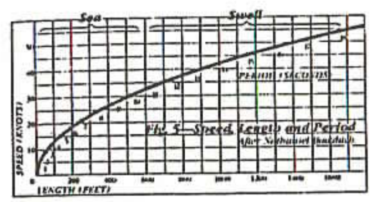


Fig. 5—Speed, Length and Period

Because the length, period and speed of waves all increase as the swell moves away from the generating area, it is possible to have a fairly good idea how far away from a point of observation waves were spawned. However, when making the necessary calculations, it is important to know that the time needed for a wave system to travel a given distance is double what it would take an individual wave to go as far. This is because the front wave of an advancing swell gradually disappears, transferring its energy to the following waves. The process is followed by each leading wave in succession at such a rate that the wave train advances at a speed which is just half that of individual waves. The speed at which the wave system advances is called the group velocity *[Fig. 7]*.

Still, for all their apparent symmetry, both theoretical and actual, wind waves are irregular phenomena. Even in trains of open-ocean swell, successive waves can and do differ markedly in height. For instance, in the mathematical model mentioned above, the average wave height created by winds blowing 30 knots for 23 hours over a fetch of 280 nautical miles will be 13.5 feet, however this same model tells us that the "significant wave height" generated will be 21.6 feet. "Significant wave height" is defined as the mean height of the highest one-third of the well-defined waves observed at a given point on the ocean's surface. Usually, as in this example, the significant wave height is about one-and-a-half times the average wave height. However, the average height of the top ten percent of these significant waves will be 27.6 feet. This means that, within a particular wave train, about one wave in a thousand (perhaps one every four hours) will be twice the average size!

One explanation for observed differences in wave height is the interference of one wave train with another. When the peak of one wave synchronizes with the trough of another wave, there is a distinct dampening effect. Conversely, the synchronicity of crests causes wave energies to combine so that the resulting wave can be much larger than either of the two waves that coincided. The swell pattern resulting from the confluence of two or more open-ocean wave trains results in a cycle of larger and smaller waves. Closer to shore this pattern is termed "surf beat" and the larger groups of waves thus created are called "sets."

The most spectacular example of the synchronicity of wave crests (often in combination with other factors) is the phenomenon of "rogue" waves. Rogue waves are statistical probabilities that on rare occasions emerge out of the land of the theoretical to haunt some of the most trafficked sea lanes of the world.

Rogue waves are solitary giants formed out of the convergence of extreme natural forces; they rise to unusual height and mass. Inevitably ships at sea come into contact with some of these wind-generated, gravity-propelled monsters. There are a number of remarkable stories of such encounters in nautical records, but how many other encounters left no tongue alive to tell is food for speculation.

In his authoritative book, *Waves and Beaches*, Willard Bascom cites a number of meetings with rogue waves. A sampler:

"In February 1883, the 320-foot steamship *Glamorgan* out of Liverpool was beating through heavy Atlantic seas at night when it was 'totally submerged by one tremendous wave.' The wave swept away the foremast, all the deckhouses and the bridge (with the captain and seven crew in it). It stove in all the hatches and the engine room was flooded. The ship sank the next morning, and the 44 who escaped in lifeboats told the tale of the one great wave.

"On another Atlantic crossing, the 1,000' *Queen Mary* was serving as a World War II troopship in 1942 when, with 15,000 American soldiers aboard, she encountered a winter gale 700 miles off the coast of Scotland. The seas were quite large but also quite manageable for the huge ship. Suddenly 'one freak mountainous wave' slammed broadside into the *Mary*, and she 'listed until her upper decks were awash, and those who had sailed in her since she first took to sea were convinced she would never right herself.' After hanging on the brink of capsizing for a few eternal seconds, the great ship finally righted herself again.

"More recently off Greenland, the *Mary*'s sister ship, *Queen Elizabeth*, took a wave over the bow that was so large it flooded the bridge 90' above the waterline.

"In 1966, 800 miles off New York, the Italian liner *Michelangelo* plunged into a gigantic trough that was followed by a huge solitary wave that crumpled the flare of the ship's bow and broke out the inch-thick glass in the bridge windows some 80 feet above the waterline, injuring hundreds of passengers (and killing three).

"In July 1976, the tanker *Cretan Star*, loaded with 29,000 tons of light crude oil, was struck by a huge wave and sunk in the Indian Ocean not far from Bombay. An inquiry reported that the southwest monsoon reaches its greatest strength in July off Bombay and periodically piles up 'episodic waves of vast proportions.'"

In exploring the probability of the occurrence of single large waves, Dr. Lawrence Draper of the National Institute of Oceanography in England used the "Statistics of a Stationary

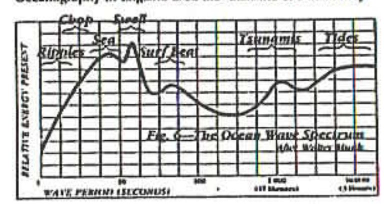


Fig. 6—The Ocean Wave Spectrum

Lighter than cork
I danced on waves
in the salt air—

Waves,
those eternal victi
tossers, so to say...

—Arthur Rimbau

Random Process" to show that one wave in 23 is over twice the height of the average wave, one in 1,175 is over three times the average height, and one in 300,000 is more than four times the average wave height. Put these statistics to work along a stretch of water known as South Africa's "Wild Coast" and you might expect calamity aplenty, and, indeed, that's what you get.

One characteristic of waves is that a following current increases wave lengths and decreases wave heights, while an opposing current has the opposite effect, decreasing the length and increasing the height, thus also steepening the face of the wave. A strong opposing current may well cause the waves to break, even in deep water. Off that southeastern coast of Africa, where the continental shelf abruptly drops away, the Agulhas Current sweeps in hard against this immovable barrier, concentrating the massive southwest flow of water into a relatively narrow stream. The current moves at four to six knots, providing a fast, economical shipping lane for ships moving south. However, when storms to the southwest pump waves around the Cape of Good Hope and up into the channel, the wave length of the swell can be shortened dramatically and the wave steepness increased to precipitous angles. Under certain conditions the unusually swift current here actually doubles the height of the waves pushing upstream. The giants that are created are called "Cape Rollers," and when the statistically predictable rogue wave moves into the current, the result can be catastrophic.

To make matters even worse, waves are refracted, or bent, toward the higher-velocity current, concentrating more wave energy over the strongest current, and possibly even trapping waves there. As Bascom points out, when a ship moving in the current at 18 knots (nine meters per second), assisted by the current of four meters per second, encounters a wave moving at ten meters per second, the velocity of the collision is the sum of these, or 23 meters per second. Since the force of impact is proportional to the square of the velocity, the current nearly doubles that force. "If," says Bascom, "the wave is twice as high as an ordinary storm wave, a ship is likely to be in trouble."

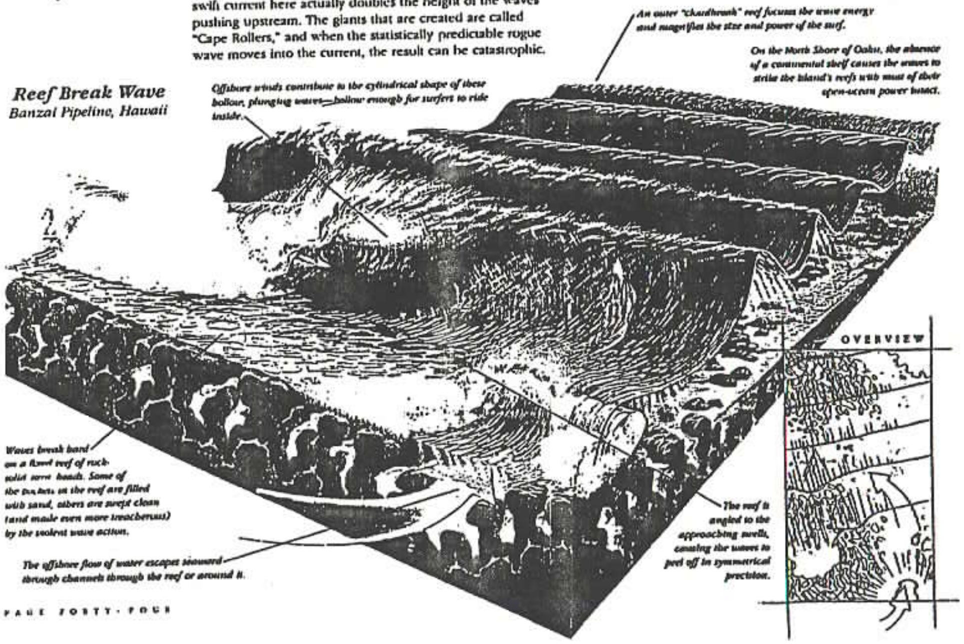
Untold vessels have been lost off the Wild Coast over the centuries. One account from Bascom of a ship that survived conveys the essence of the situation: In December 1969, the middle of the southern summer, the 102,000-ton Swedish tanker *Artemis* ran through a storm on its way down the Wild Coast. Captain L.J. Tarp reported that one wave came over the ship's bow and continued rolling down the deck at such height that it hit and flooded the wheelhouse five decks up.

The complex network of wave relationships—combining, dampening, crossing, overtaking—is a continual dynamic of the ocean surface. It is part of what has made the ocean an enduring frontier and a mystery. Always, far beyond the horizon, new storms pinwheel into being, urging up new waves, new swells, out from the otherwise vast, implacable face of the world's oceans.

Most of us will be completely unaware of their distant arising, their silent passage across the empty miles. Most of us will only become aware of them as they emerge out of the distance, touch bottom, rise and finally burst into white glory. Only then, as breaking waves, will their full potential be revealed to us.

Reef Break Wave

Banzai Pipeline, Hawaii



Breaking Waves

When long, fast, smooth open-ocean swells move into shallower water, their character begins to undergo a significant transformation. When the depth of the ocean becomes less than half the length between the crests of two successive waves, the speed of a wave is no longer governed by its length, but by the depth of the water; the speed of a wave is now proportional to the square root of the depth of the water it is moving through. It is at this point that ocean swell changes to ground swell. This is where the study of deep-water waves ends and the study of shallow-water waves begins. This is the transition zone between swell and breaking waves.

When swell moves into water less than half its wave length deep, the wave begins to "feel" and be affected by the bottom. The contours of the basin within which the wave travels begin to modify the wave's behavior through a process called "refraction." Refraction here refers to the result of the slowing of waves as they move into shallowing water. This results in a bending of the wave fronts to align themselves to the contours of the shoaling bottom.

Because the speed of a wave in shallow water is a function of the depth, swell refracts as it responds to submarine contours. Since waves slow as the bottom shoals, swells moving laterally toward a sloping coast are bent toward the shore. Similarly, wave energy converges and focuses over shallow ridges *[Fig. 8a, 8b]*, while it diverges and disperses over deeper submarine trenches.

Blair Kinsman reminds us that, "the only feature of a wave as we see it from the beach that has been left unaltered from its deep-water state is the period. You can't tell what direction the waves are running offshore from the angle at which they approach the beach." In fact, as waves move into increasingly shoal water, they begin to slow, the wave length shortens, and the low, sloping mounds begin to rise up out of themselves.

Certainly some amount of drag is produced by the interaction of wave energy with a shoaling bottom; some energy is certain to be released in this way. However, the popular belief that friction slows waves down in shallow water while the crests continue to move more rapidly, and so trip over themselves, seems less popular today than in the past.

Surfer-author-musician John Kelly, Jr. of Hawaii ascribes the change in speed—and in wave height—to deflection, to the idea that ocean wave energy obeys the same laws that control the deflection or reflection of light waves, and that the angle of reflection equals the angle of incidence.

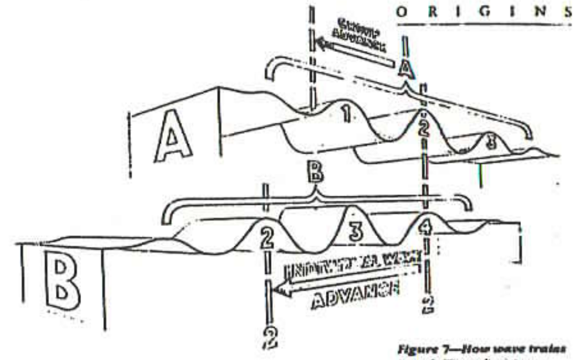


Figure 7—How wave trains travel: Waves die out over distance and are replaced by following waves at such a rate that the group advances at just half the speed of the individual waves.

In *Surf and Sea* Kelly writes: "Since the ocean bottom is a fixed boundary, the deflected wave energy is focused upward to a degree that depends on the angle of the rising bottom and appears at the other, flexible boundary of the medium in the form of the rising crest—in effect, an inversion of the wave's energy. As more and more of the wave energy is deflected upward by the confining space of shoaling water, the crest mounts proportionately higher. Here we find an explanation for the slowing of the wave: It is due to the fact that the wave energy, bouncing, as it were, off the bottom and being deflected to the crest, travels a greater distance. The detour consumes time, thus slowing the advance of the wave form even though the energy itself continues to travel in its watery medium at a constant speed."

Although this description might impress some oceanographers as a mere flight of fancy, it does portray a clear (if untrue) image of the dynamics that lead to the breaking of the ocean wave.

As was said earlier, waves in deep water will begin to break when their height is greater than a seventh of their wave length. The maximum stable profile angle of the crest of a wave is, therefore, about 120 degrees. Steeper than this, the wave character begins its final dramatic transformation. In very shallow water, when waves break as they approach land, they will reach this critical angle in a water depth of about 1.3 times the wave height. In other words, a three-foot-high wave will break in approximately four feet of water. It is as waves approach this "limit of their containment" that the most dramatic moments of their lives are played out in the surf zone.

Whatever the lawful causes—friction or deflection—as waves encounter the rapidly shoaling water associated with most beaches, they are said to peak up. That is, their height increases rapidly. At the same time the shallow water causes the wave length to decrease (because as a wave is slowing, the waves behind are catching up); the result is a suddenly steepened wave. Therefore, in a very short distance, the crest

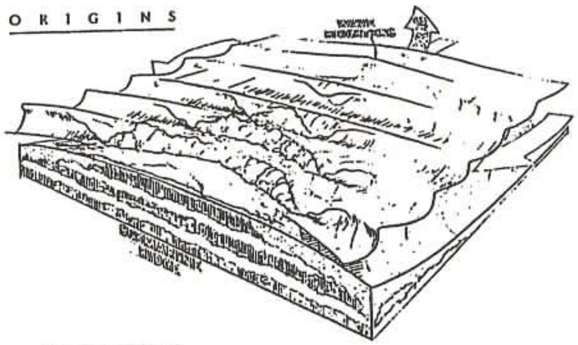


Figure 8—Refraction of waves over a submarine ridge: The bending of waves as they slow in shallowing water focuses their energy over the shoal area.

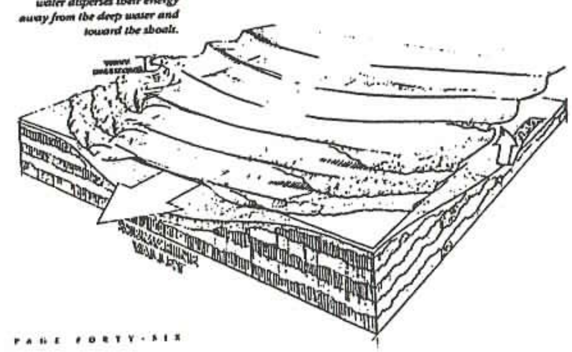
angle decreases below the critical 120 degrees and the wave becomes unstable. The crest, moving more rapidly than the water below, falls forward and the wave form collapses into turbulent confusion, which uses up most of the wave's energy.

Perhaps the leading popular authority on ocean wave phenomena is Willard Bascom. Some thoughts from his *Waves and Beaches* on the dynamics of breaking waves:

"As the swell moves into very shallow water, it is traveling at a speed of 15 to 20 miles an hour, and the changes in its character over the final few dozen yards to shore come very rapidly.

"In the approach to shore, the drag of the bottom causes the phenomenon of refraction...and one of its effects is to shorten the wave length. As length decreases, wave steepness increases, tending to make the waves less stable.

Figure 9—Refraction of waves over a submarine canyon: The bending of waves as they slow in shallowing water disperses their energy away from the deep water and toward the shoals.



Moreover, as a wave crest moves into water whose depth is about twice the wave height, another effect is observed which further increases wave steepness. The crest 'peaks up.' That is, the rounded crest that is identified with swell is transformed into a higher, more pointed mass of water with steeper flanks. As the depth of water continues to decrease, the circular orbits (the movement of a particle of water within the wave) are squeezed into a tilted ellipse and the orbital velocity at the crest increases with the increasing wave height.

"This sequence of changes in wave length and steepness is the prelude to breaking. Finally, at a depth of water roughly equal to 1.3 times the wave height, the wave becomes unstable. This happens when not enough water is available in the shallow water ahead to fill in the crest and complete a symmetrical wave form. The top of the onrushing crest becomes unsupported and it collapses, falling in uncompleted orbits. The wave has broken; the result is surf."

The energy released in a breaking wave is tremendous. All of that stored wind power—transported silently for so many miles—at last bursts out of its liquid confines with a thunderous roar of liberation. The total energy of a wave ten feet high and 500 feet long can be as high as 400,000 pounds per linear foot of its crest. The impact pressure of such a breaking wave can vary from 250 to as much as 1,150 pounds per square foot. Larger waves have been recorded to exert a force of more than three tons—6,000 pounds of pressure—per square foot in the surf zone!

Echoing the combined energies of the many forces out to sea, ocean waves approach the shore in irregular patterns—cycles of smaller waves and larger waves created by the reinforcing or cancelling interaction of different wave trains. Groups of bigger waves are called sets; long intervals between sets are called lulls. The pattern of sets and lulls—the surf beat—is the pronounced rhythm of the ocean's language, the cadence of its voice.

Waves and Surf

In general, there are three forms of breaking waves: surging breakers, spilling breakers and plunging breakers *[Figs. 9a, 9b, 9c]*.

Surging waves are associated with relatively deep-water approaches to steep beaches. The incoming wave peaks up, but surges onto the beach without spilling or breaking.

Spilling waves are generally produced by a very gradually sloping underwater configuration. The wave peaks up, the crest angle shrinks to less than 120 degrees, but the release of energy from the wave is relatively slow. Spilling waves typically have concave surfaces on both front and back sides.

Plunging breakers are the most dynamic, exciting manifestations of wave action on the ocean. Their rounded backs and concave, hollowing fronts result where an abrupt shoaling of the bottom creates a sudden deficiency of water ahead of the waves, which can be moving at near open-ocean velocity; water in the trough rushes seaward with great force to fill the cavity in the oncoming wave. When there is insufficient water to complete the wave form, the water in the crest, attempting to complete its orbit, is hurled ahead of its steep forward side, landing in the shallow

trough. The curling mass of water (called a "tube" by surfers) surrounds a volume of air, often trapping and compressing it. When the trapped air breaks through the curtain of water that surrounds it, there is often a geyser-like burst of spray and mist. Often, too, the mist is expelled out of the open end of a well-defined tube, like smoke from the barrel of a gun. Riding ahead of such a blast of vapor is where a lot of surfers would like to be.

Surfers, animals (including porpoises and seals) and boats are able to ride waves due to the resultant of three forces—the total weight of the vehicle (i.e., surfer and surfboard), the total buoyancy of the vehicle (including planing force), and the "slope drag" created by the angle of the wave's face. When this slope drag is greater than the hydrodynamic drag (water resistance), the vehicle moves at the approximate speed of the wave crest.

One of the major skills required for a surfer is getting the surfboard moving fast enough at an angle precise enough so that the slope drag takes over the work of propelling the vehicle just as the wave rises up beneath him. Once he's up and riding, the surfer can move considerably faster than wave-crest speed by maneuvering sideways across the face of the wave.

Although humans are the most common surfers today, the act of riding waves is an ancient custom for porpoises, seals, sharks, killer whales, and fish and birds of all kinds. Seals and porpoises are terrific surfers; their instinctive familiarity with the liquid medium allows them to be the most subtle and eloquent wave riders of all.

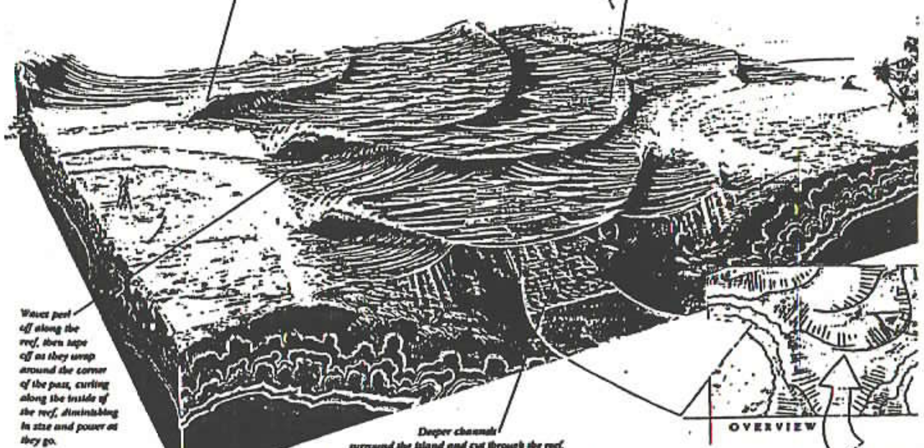
Because porpoises and seals have neutral buoyancy, they are able to tilt themselves to the correct slope angles of underwater constant-pressure surfaces (literally wave planes within wave planes) and catch the waves there, so that often they are seen in a subsurface mode, imbedded in the wave face as they surf across a transparent wall of water. However, these creatures are also able to break through the plane of the wave face and surf on the outside surface of the wave in a more conventional manner. Interestingly, some human bodysurfers have also learned the art of surfing the underwater constant-pressure surfaces.

Just as not all beaches and bottom configurations help to develop plunging waves, not all beaches—relatively few, in fact—are conducive to the creation of waves for surfing. A perfect wave for surfing is one that is refracted in such a way as to concentrate its power in a given area of the wave band, then "peels" off laterally over a relatively abrupt, shallow bottom so that the wave is a plunging breaker with an extremely concave or "hollow" face. When the crest of such a wave pitches out toward the trough, it can then complete a tunnel-like formation, creating the ideal "barrels" that the best surfers travel the world to find.

Do not move
Let the winds sp
that is paradise

—Ezra P

Reef Pass Wa
Tavarua Island, Fi



In the dramatic last seconds before lines of swell become breakers, waves respond to the sudden shallowing of the water depth by gaining considerably in height (sometimes double or more the swell height), developing a critical concave face, and assuming a beach-facing profile that reflects the immediate characteristics of the bottom shape directly under the wave. These local bottom configurations determine the final form of the breaking waves. In general, there are several types of wave "breaks."

Relatively straight sandy or gravelly beaches with a gentle slope create "beach break" waves—a pattern of peaking waves with periodic channels to carry the advancing water back out through the surf zone. Such waves break on sandbars or "gravelbars," deposits of material mobile enough to be arranged and rearranged at the whim of swell, tide and wind. Often the beach face is scalloped in a regular pattern of "cusps" reflecting the regularity of the coastline, the subsequent regularity of the refraction that concentrates and disperses the wave energy, and the mathematical relationship between the advancing force of waves and the receding flow of water.

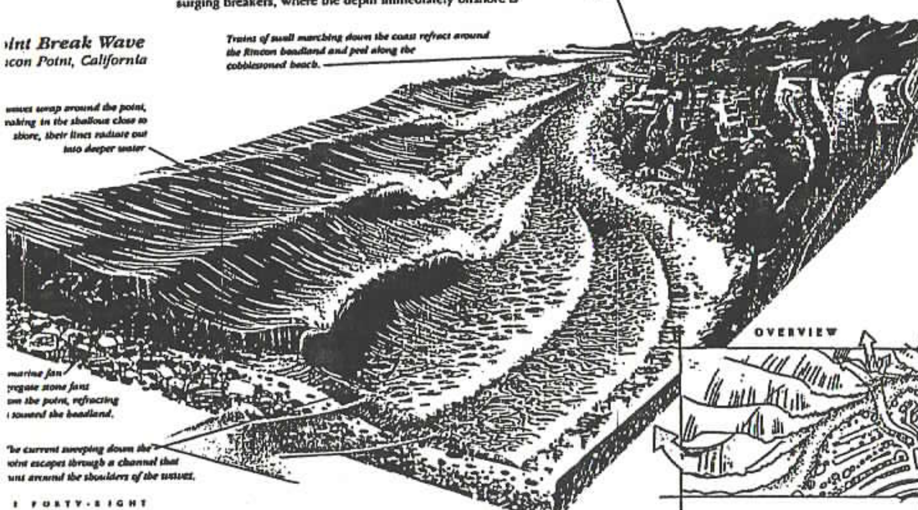
Outgoing currents of water between areas of breaking waves are called "rips" or ripsides; in large surf they are capable of becoming overwhelmingly powerful channels, moving rivers of water heading back out to sea—frightening locations for swimmers, but ideal onramps for surfers wishing to make it through the near-shore "beach break" waves to catch rides in deeper water.

Very steep sand or gravel beaches are likely to produce surging breakers, where the depth immediately offshore is insufficient to greatly diminish the potential energy in the breaking waves. Thus, most of the wave energy is released directly up onto the beach face or reflects back at the incoming waves; the outgoing sheet of water creates a "backwash" effect that can double or triple the size of an approaching wave, often with spectacular effect.

Submarine formations like coral reefs, rock reefs, sunken ships and other relatively abrupt submerged or partially-submerged formations create "reef" surf—waves that break more or less abruptly and in a variety of shapes, depending on the configuration, depth and size of the obstacle.

The famous Banzai Pipeline off Oahu's North Shore is a reef break; swells radiating in from great Pacific storms to the northwest come out of very deep water to touch coral reefs more than a mile off shore. This outside reef bends the waves, focusing them in on the near-shore Banzai reef with little loss of energy. The waves rise steeply over the "outside" reef, then appear to almost disappear in the intermediate deep-water zone, then abruptly "jack up" as they rush in at the abrupt "inside" reef. There, these giants that have come so far are forced up out of themselves by the sudden wall of battered coral. Immediately there is insufficient water in the trough of the wave for the circulation of water. The

ɪnt Break Wave
ɪcon Point, California



face goes as concave as a storm pipe (hence the pipeline name), the crest becomes a "lip" of plunging water that leaps beachward to complete the cylindrical shape of the wave, creating the spectacular hollow within, followed by the familiar blast of mist as the wave collapses around the pocket of trapped air. Add to these fundamental dynamics the angled seaward face of the reef, which causes the wave to peel off to the left and (sometimes) to the right, and it would be hard to imagine a more perfect wave. And, if all this weren't enough, the prevailing wind is off the land and straight up the left-breaking faces of the waves. This has the effect of smoothing the faces, holding them up longer, and allowing them to grow even hollower before breaking.

It is this "shoulder" effect, where the wave can peel along the angled edge of a shallow reef, that makes a wave

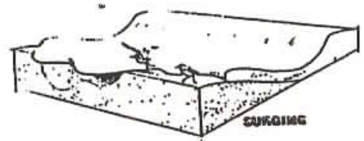
of interest to surfers. A triangular-shaped reef, with its apex pointing to sea, will tend to create an initial peak wave, then waves will peel off in either direction as the lines of swell refract and converge alongside the reef. The result can be symmetrical, twisting cylinders of great beauty and finesse.

Assuming a perfect equilateral triangle with its base parallel to shore, such a reef would create the most perfectly balanced peeling waves when the lines of swell approached it squarely. Should the swell direction be from one side or the other, the wave on the near side of the triangle will tend to peel off too fast (to "close out" or "section" ahead of the rider), while the wave on the far side will be "mushier" and less hollow—more of a spilling breaker—as it wraps around the apex of the triangle and disperses its energy into the deeper water beyond.

Peeling waves can also be created by "passes" in coral reefs—channels created in the living formations by the runoff of fresh water from the tropical island land masses which these living reefs tend to surround. Here, the typical surfable wave will wind off the end of one shallow shoulder of reef, peeling toward a deep channel. Such waves can be a mile or more out from shore, and because the reef itself is usually submerged, these walls of water have an isolated and unpredictable beauty.

The one-directional peeling of the reef-pass wave is similar to the peeling of a typical "point" wave, created when lines of swell wrap around a coastal promontory or protrusion and break—often with remarkable regularity and evenness—as they refract around the bend at a relatively constant distance from the curved shoreline.

One fine example is the wave at California's Rincon Point near Santa Barbara—a beautiful triangle of cobblestoned shoreline extending roughly a half-mile from the inside cove to the apex of the point where a creek spills out into the Pacific.



The machine-like regularity with which the swells fan around the point and trace the even shape of the shallow bottom with a surging carpet of white water is a moving impression, to the surfer and wave watcher alike.

Whereas the exposed tip of such a point or promontory will generally have a rocky, gravelly or boulder-strewn beach, the bay into which point waves peel is typically a repository of fine sand. This is because, once a wave has broken into a tumbling chaos of foam, it has lost its internal oscillatory motion. Instead, the particles of water are actually driven forward by the momentum of the wave action. This movement of water toward the beach translates into a strong beachward current along points and promontories. It is this current that is able to move large amounts of sand and other fine particles along the point and into the bay. As energy, momentum and wave speed dissipate, the sand drops to the bottom or washes ashore. For this reason, peeling point waves will often end in an abrupt beachbreak "close-out," as a long section of wave suddenly shoals over a sandbar or surges up onto a straight beach.

Whatever their form, whatever their size, whatever their cause, waves are relentless proof of the power of great outside forces over our lives—the same forces that suspend our world in space, in an intricate web of physical laws—the same forces that sustain the very fabric of our reality.

Waves are carriers of a very important message: that we are not alone, that we are part of a larger whole, and that we are an important enough part of the whole to deserve this lavishly beautiful and magnificent planet. Waves are living proof that something in nature and the universe has quite a high opinion of our intelligence and our capacity for appreciation.

Poetically, waves may be the lips of the sea, eternally communicating—simultaneously—to an infinite number of landfalls. Scientifically and physically, waves are great translators or transformers of energy. If we owe all life to the sun, then ocean waves are, literally, messengers of the gods.

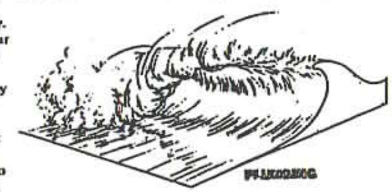


Figure 10—Types of waves: Depending on local bottom conditions and the steepness of the beach, waves break in three distinct fashions—surging, spilling and plunging.

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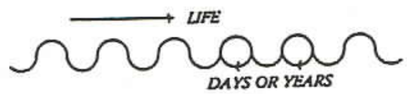
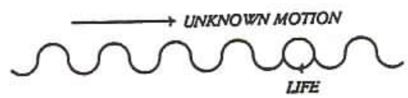
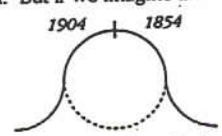
As we should know from the study of undulatory vibrations in the world of physical phenomena, every wave comprises in itself a complete circle, that is the matter of the wave moves in a completed curve in the same place and for as long as the force acts which creates the wave. We should know also that every wave consists of smaller waves and is in its turn a component part of a bigger wave. If we take, simply for the sake of argument, *days* as the smaller waves which form the bigger waves of years, then the waves of *years* will form one great wave of *life*. And so long as this wave of life rolls on, the waves of days and the waves of years must rotate at their appointed places, repeating and repeating themselves. Thus the line of the fourth dimension,

the line of life or *time*, consists of wheels of ever-repeating *days*, of small circles of the fifth dimension, just as a ray of light consists of quanta of light, each rotating in its place so long as the primary shock which sends forth the particular ray persists. But in itself a *ray* may be a curve, a component part of some other bigger wave.
The same applies to the line of life.





If we take it as one great wave consisting of the waves of days and years, we shall have to admit that the line of life moves in a curve and makes a complete revolution, coming back to the point of its departure. And if a day or a year is a wave in the undulatory movement of our life, then our whole life is a wave in some other undulatory movement of which we know nothing. As I have already pointed out, in our ordinary conception life appears as a straight line drawn between the moments of birth and death. But if we imagine that life is a wave, we shall get this figure:



The point of death coincides with the point of birth.

— *P.D. Ouspensky*

A New Model of the Universe

PRODUCTION NOTES

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Editorial Director: Drew Kampion
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Photography Editor: Art Brewer
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Water and other liquids

Garrett Wren

Water Classification

Water is one of the more difficult and complex effects to animate. It comes in many different varieties (classifications), each requiring its own unique approach in terms of animation as each has its own set of physical laws and forces which the water must adhere to. Examples of some classifications are : splashes, ripples, waves, rain, water falls, water fountains, water reflections, geysers etc...

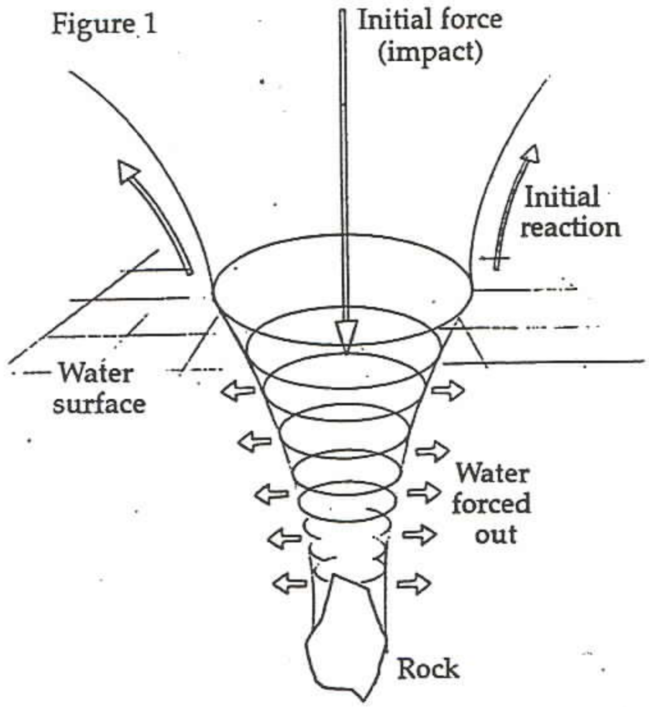
Also within each classification of water there are numerous sub classifications which also must be considered. For example, with waves you can have rolling waves, choppy waves, swelling waves, tidal waves, shore surf, calm sea etc... In all of these examples there can be an infinite amount of possibilities and choices to be made, too many in fact to cover in detail here; the best advice that can be given overall is analyze exactly what is happening and try to understand the forces that come into play and influence the outcome. The following notes will study in detail a splash and touch on waves and other liquids.

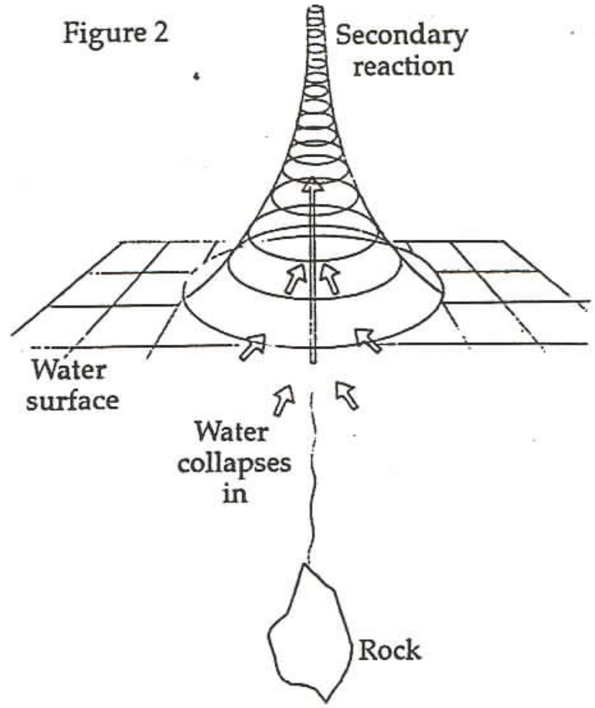
Splashes

The primary and secondary forces causing a splash to occur.

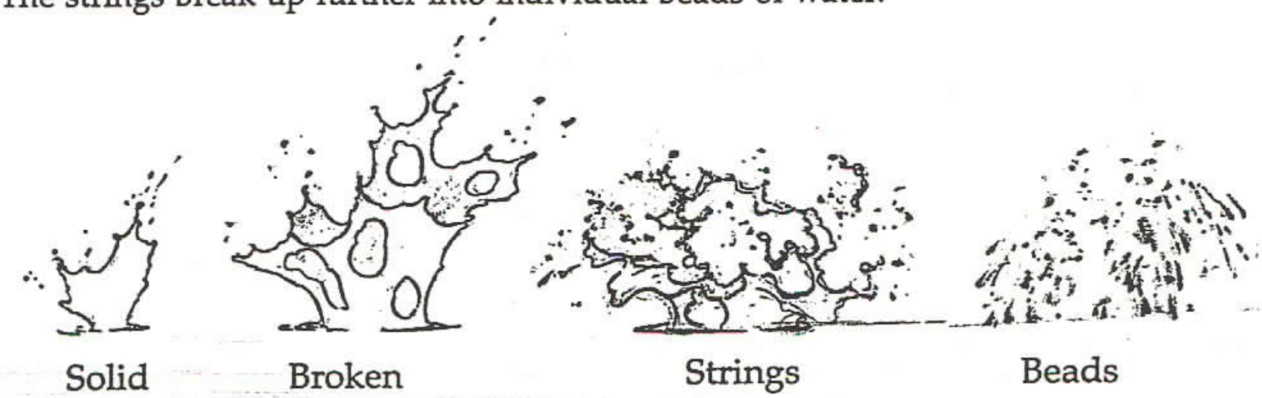
A primary splash is caused by the disruption of the surface water by an object or projectile entering the water at any given angle, speed or motion. Its shape whether its aerodynamic or a broad flat surface also heavily influences the type of splash that occurs. Generally speaking, the more aerodynamic the object is, the less violent the reaction will be. As the object quickly submerges beneath the surface it creates an turbulent air pocket behind it which is quickly filled in from directions and explodes upwards and outwards. This is known as the secondary splash. Remember, both splashes (even though caused by the same object) have different forces acting on them to provide different reactions (see fig 1 and 2).

In animation the primary splash is usually done as the biggest and the most detailed splash and the secondary one is either left out or added as a subtle after-effect. Its done this way for many reasons, (including artistic ones) but mainly it helps simplify the design or simply lessons the amount of work involved.



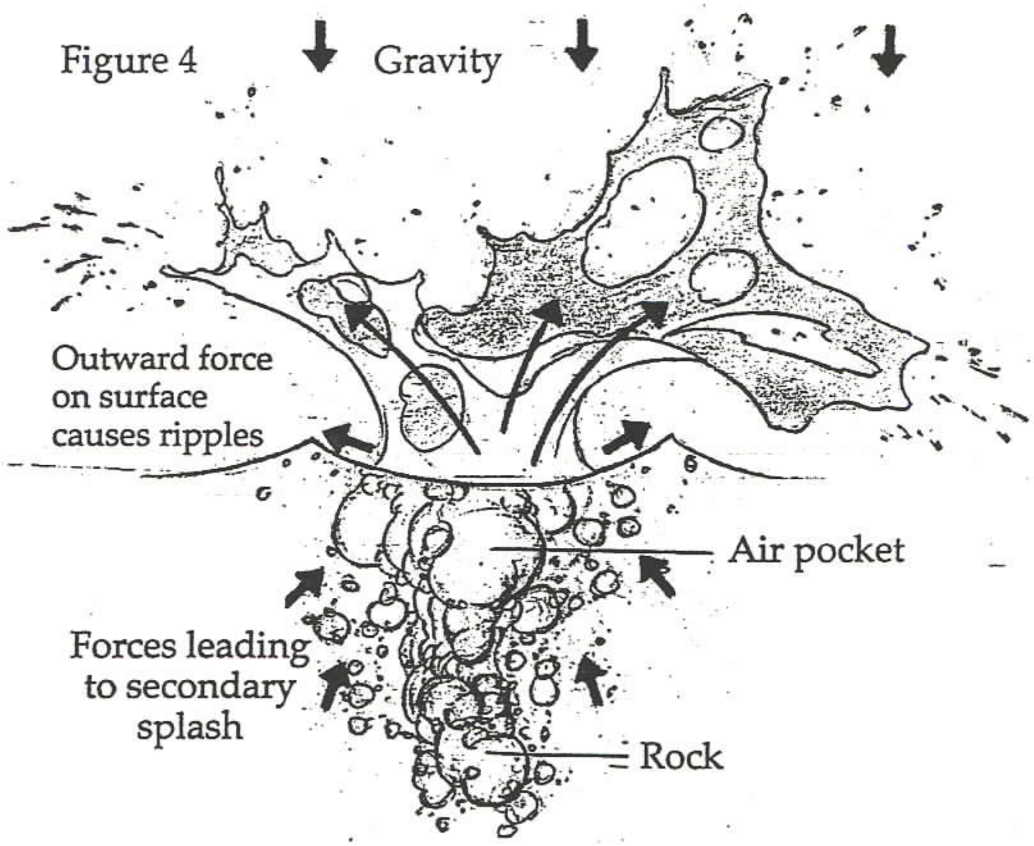


There are four distinct forms through which a primary splash evolves:
1. Solid sheets of water which form at the beginning.
2. Sheets of water develop holes to become broken sheets of water.
3. Holes expand to develop strings of water.
4. The strings break up further into individual beads of water.



Each of these four stages results from the surface tension simply trying to pull the water into spherical droplets.

The size and shape of the splash are determined by the strength and angle of the impact that initially occurs. After the initial impact, gravity is the only force acting on the water. As a result, each part of the water follows a parabolic curve which is determined by its initial velocity. The slow in and slow out at the apex of the arc is called the "hang time". The length of the hang time that you employ into your splash helps determine scale or can simply make the over-all motion look more appealing, comic or dramatic. Always remember to follow your arcs and keep the speed consistent in relation to the motion.



Waves

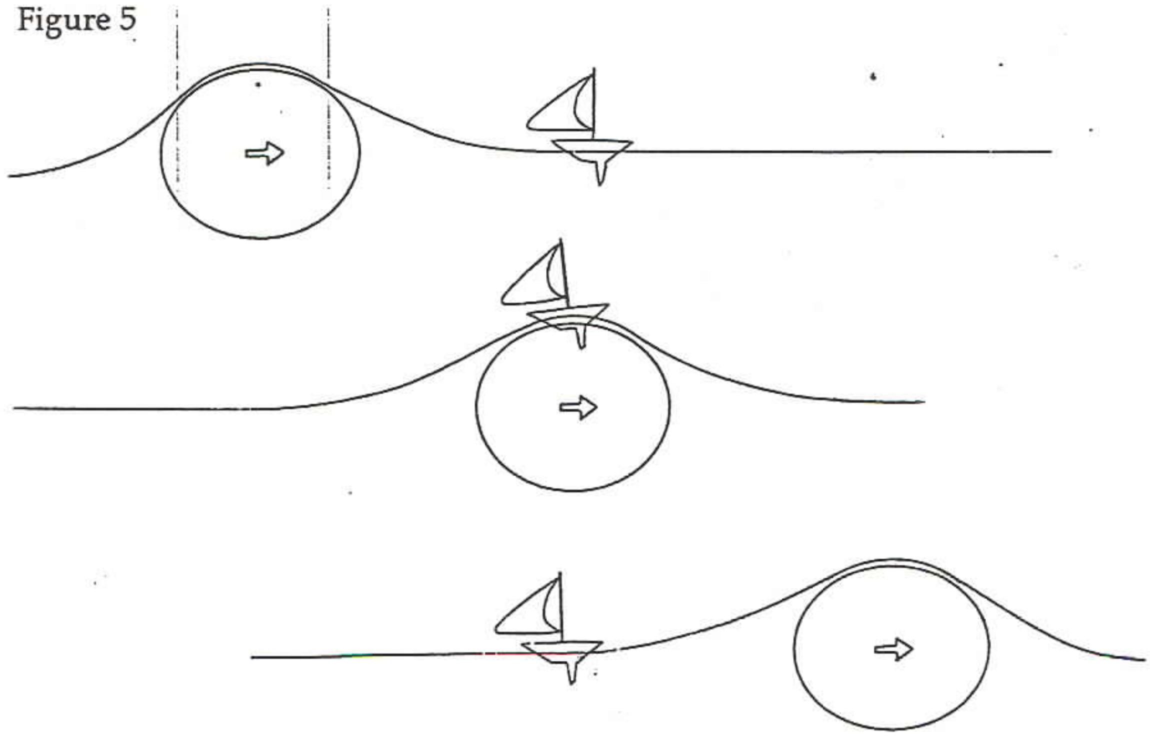
Waves are a constant body of motion continually interacting with each other and are influenced by many factors, which include wind, tidal forces, currents, the moon etc... All of these forces make up a very complex set of which are impossible to figure out or contemplate fully while trying to animate the sea. Therefore, a much simpler approach should be used. A new set of rules must be invented to help simulate the real thing. One basic method, which is probably the easiest to visualize, is to think of barrels underneath the surface moving around (see figure 5). As the barrels push forward through the water, they cause the water to rise, then lower, leaving behind the surface texture (and whatever else is on the surface) in its wake.

Remember though, waves don't always move in the same direction or at the same speed, and smaller waves constantly form out of the larger ones. Mixing up the speeds and sizes will help to create a lot of overlap and a sense of scale. When animating waves, there are an infinite amount of possibilities of motion as well as a infinite amount of designs and textural add-on's to choose from. Adding detail to the basic wave structure bond's the design and overall form together. Be aware, though, the detailing must conform to the proper perspective as dictated by the rough drawing in order to maintain it's structural integrity and a sense of believability.

Figure 6 demonstrates that if you first indicate a perspective on the rough drawing it's easier to visualize it's true form.

It will take a lot of practice before you can control your drawings - till then, the drawings will control you! Have patience and practice! practice! practice!

Figure 5



Other liquids

All liquids are bound together by varying degrees surface tension (adhesion) which are based on the liquids' viscous properties. Before venturing out to animate other liquids, a solid understanding of water and its properties is necessary in order to realistically and convincingly animate and evolve the shapes correctly. Some other types of liquids and their properties are:

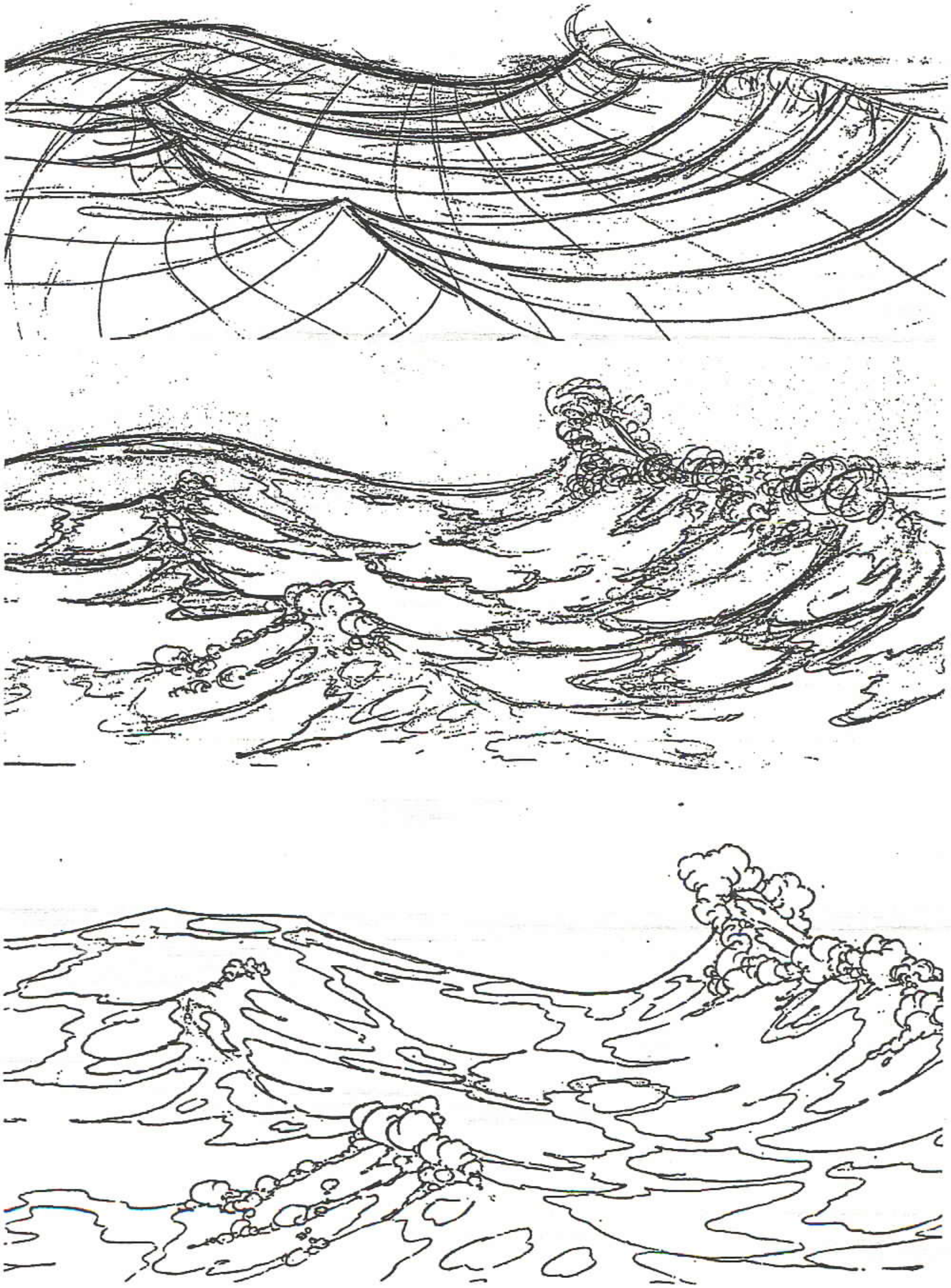
Gasoline -Has a lower viscosity than water.
-breaks apart faster

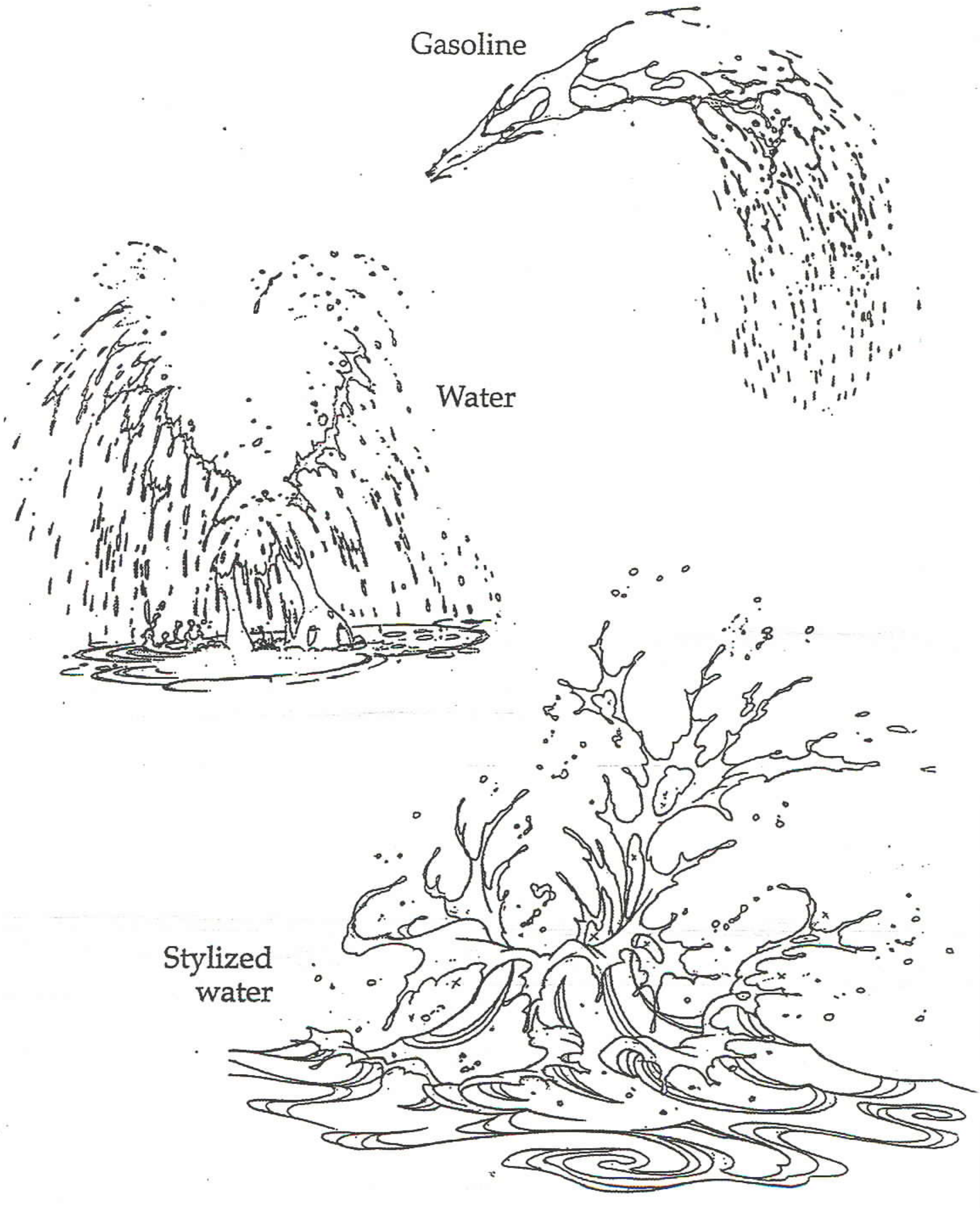
Mud -Has a higher viscosity than water
-Holds together longer
-Has more globular texture
-Breaks up mainly into strings of mud rather than beads

Tar -Has a very high viscosity
-Drags and stretches rather than breaks up
-Moves much more slowly than water

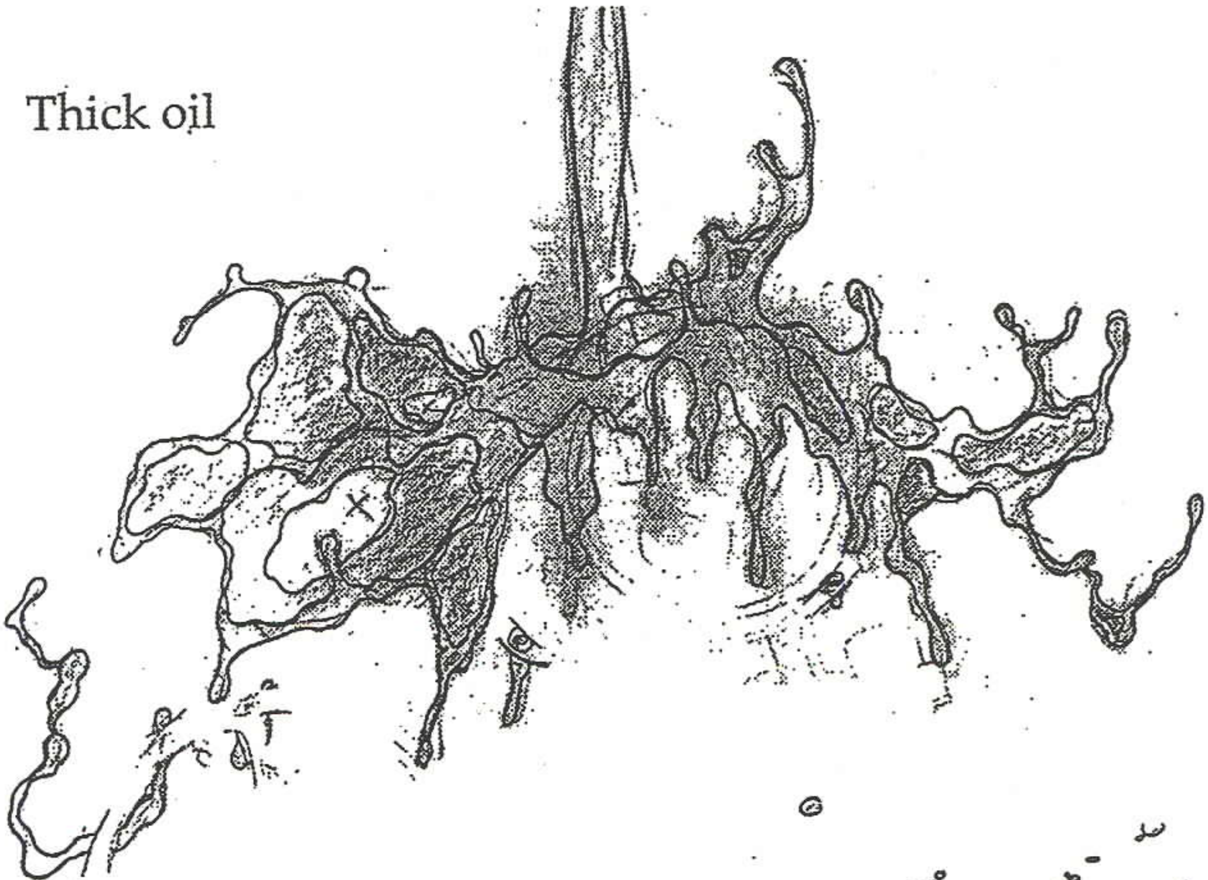
Lava -Extremely high viscosity
-Molten lave is basically liquid rock
-Flows fast at first, then becomes sluggish as it cools and solidifies
-creating fantastic shapes.

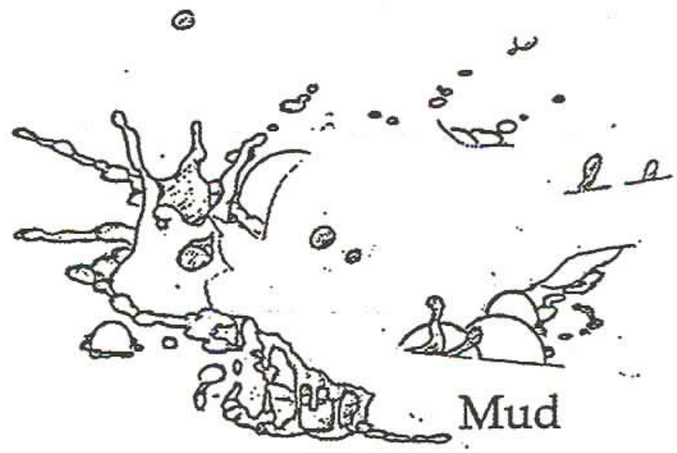
Figure 6




Gasoline
Water
Stylized water

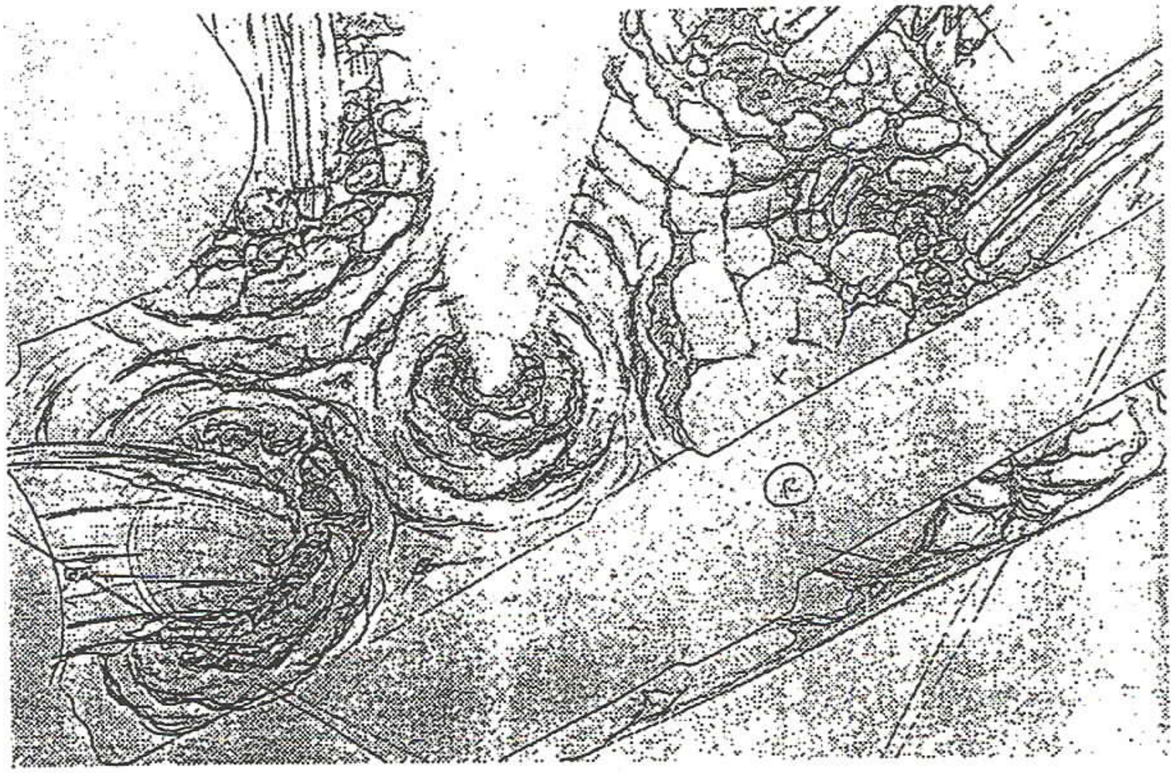
Thick oil

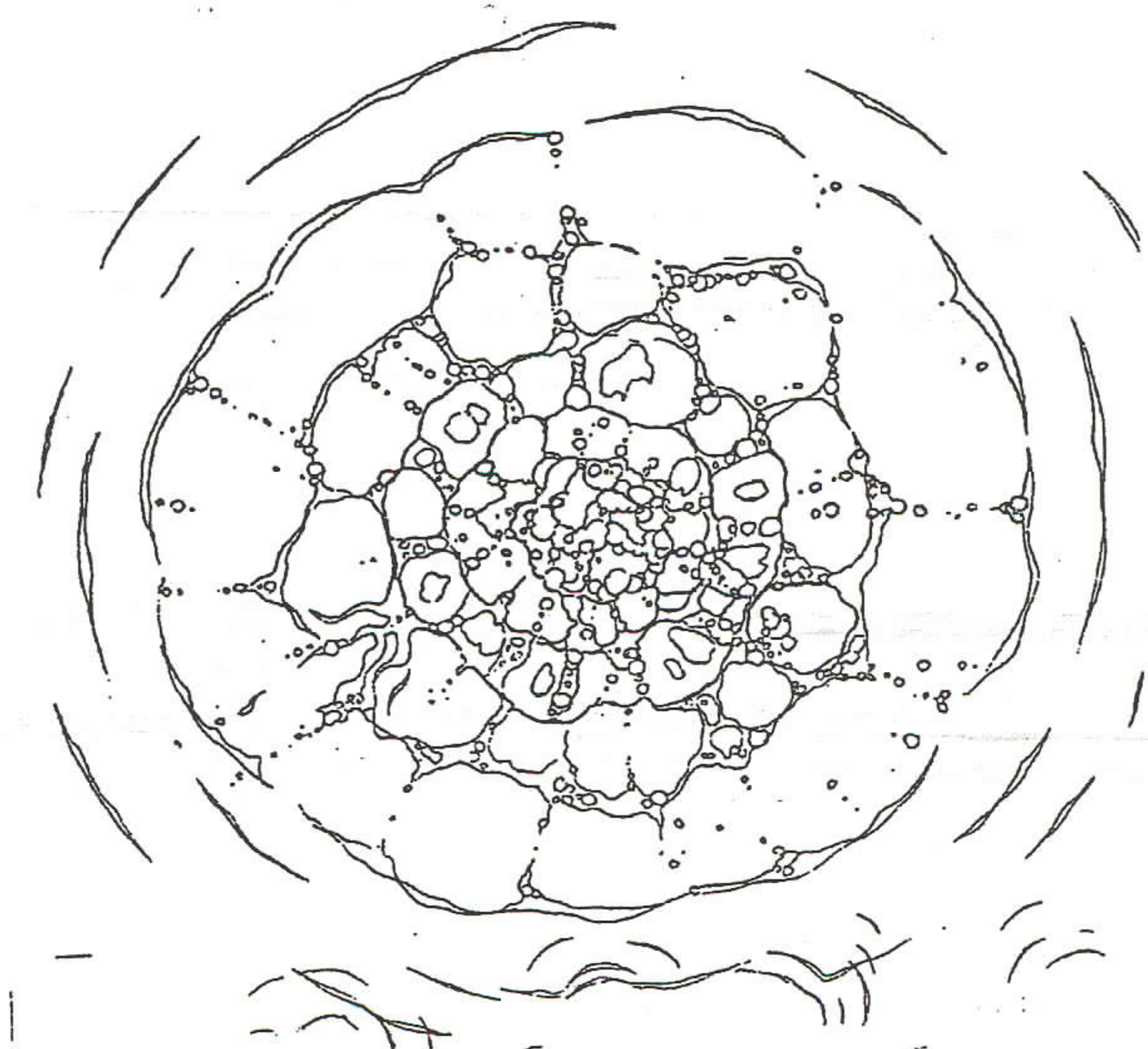


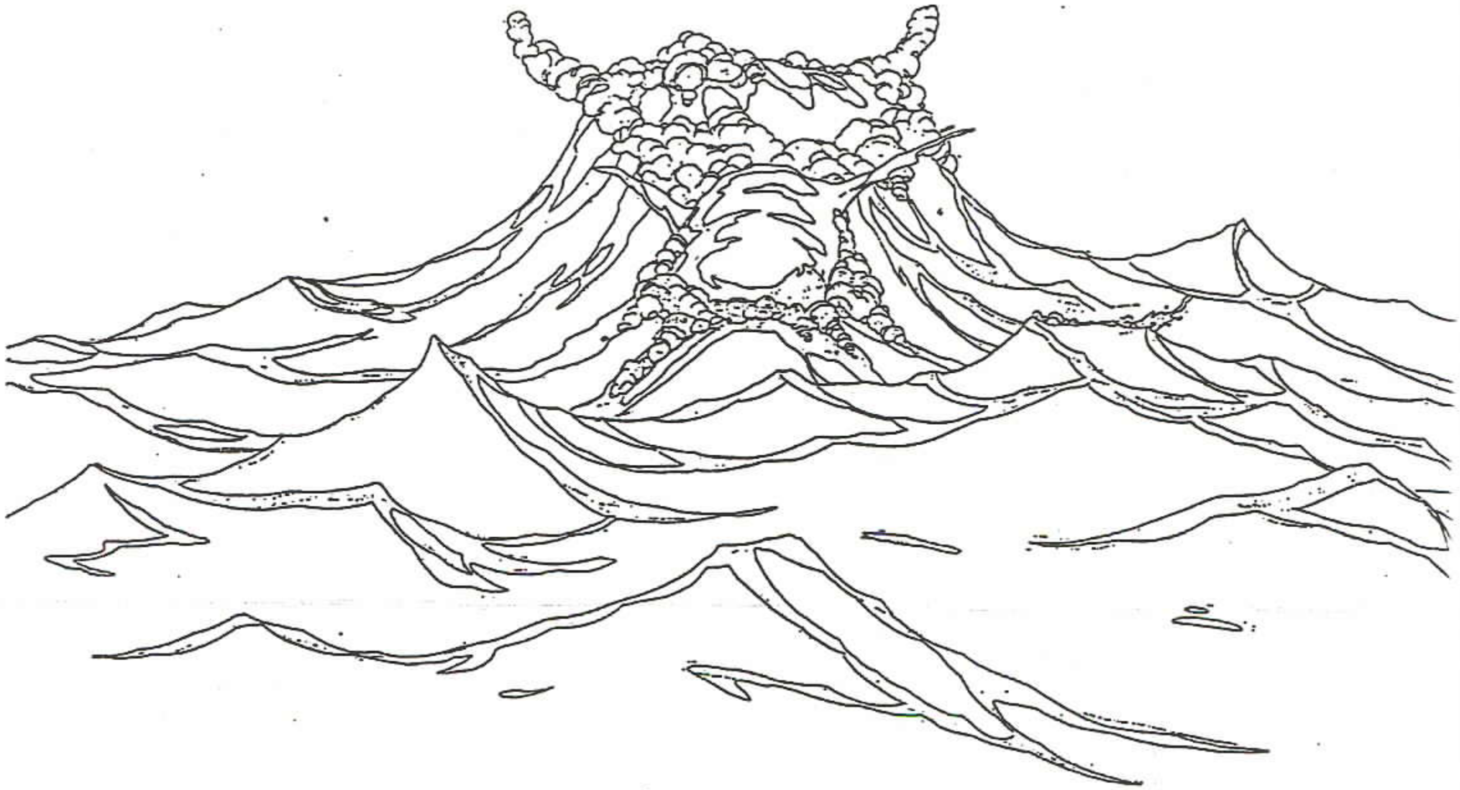


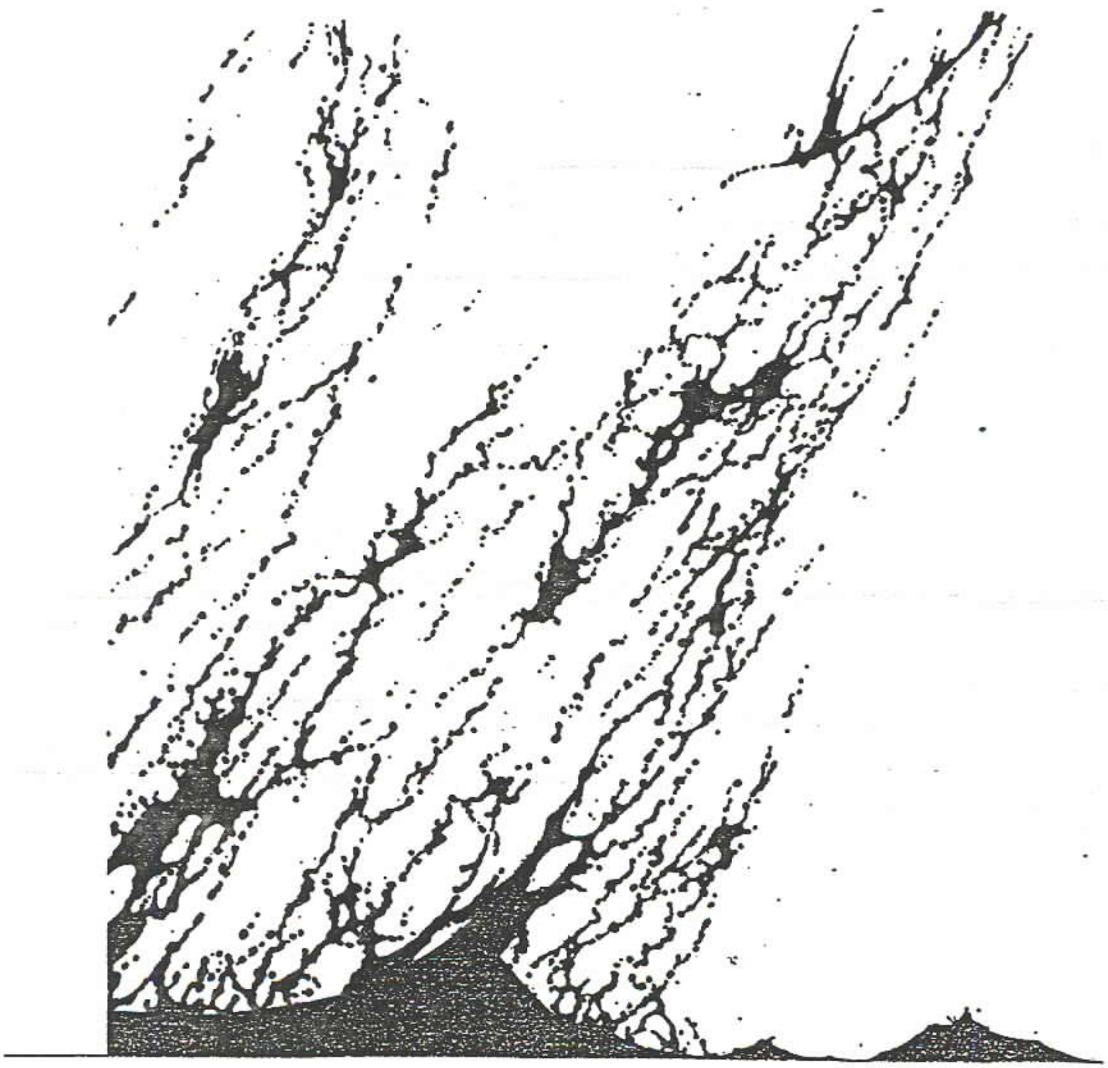
Mud

Lava









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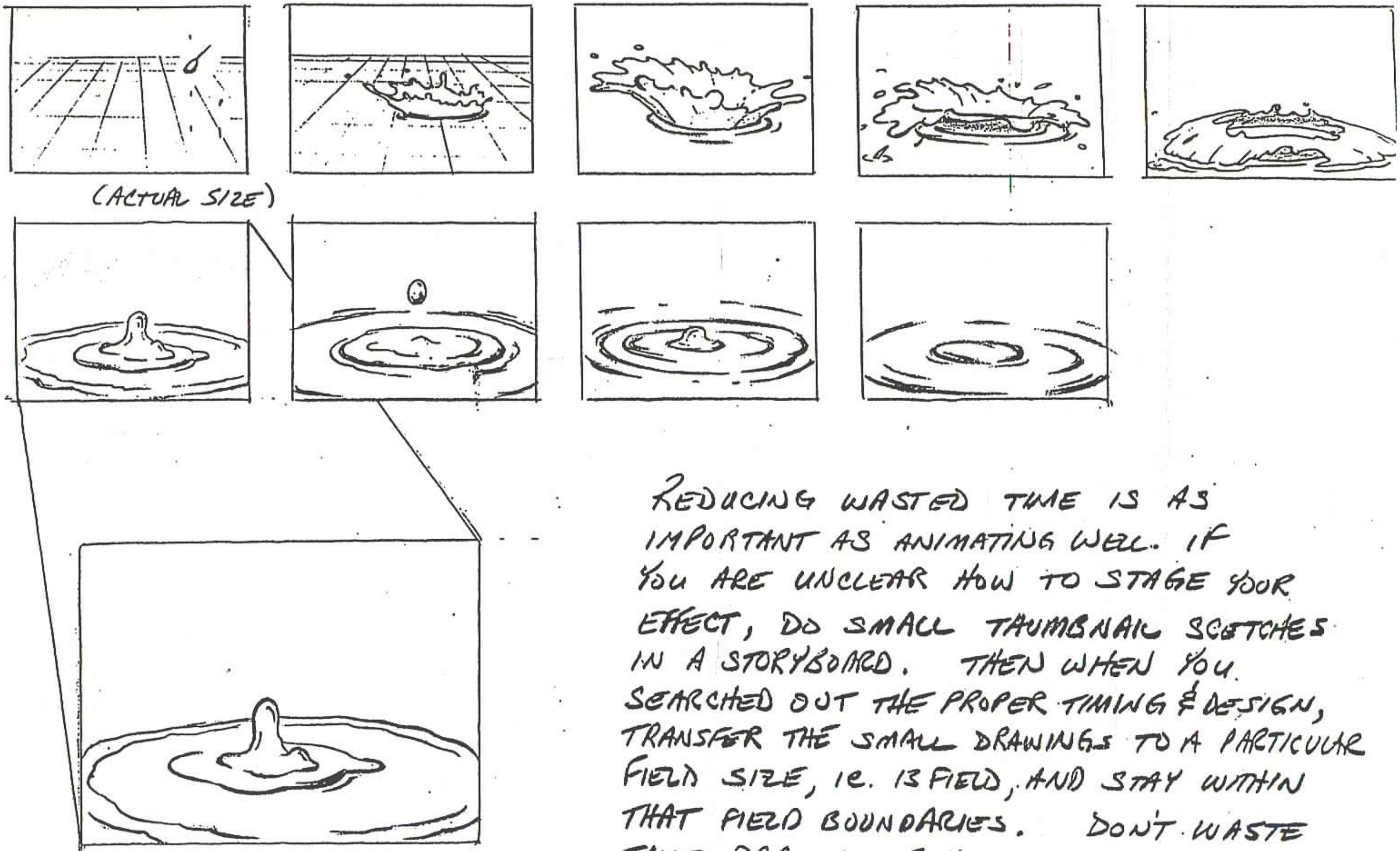

REDUCING WASTED TIME IS AS IMPORTANT AS ANIMATING WELL. IF YOU ARE UNCLEAR HOW TO STAGE YOUR EFFECT, DO SMALL THUMBNAIL SCETCHES IN A STORYBOARD. THEN WHEN YOU SEARCHED OUT THE PROPER TIMING & DESIGN, TRANSFER THE SMALL DRAWINGS TO A PARTICULAR FIELD SIZE, IE. 13 FIELD, AND STAY WITHIN THAT FIELD BOUNDARIES. DON'T WASTE TIME DRAWING BEYOND WHERE THE CAMERA WILL NOT SEE.

TH


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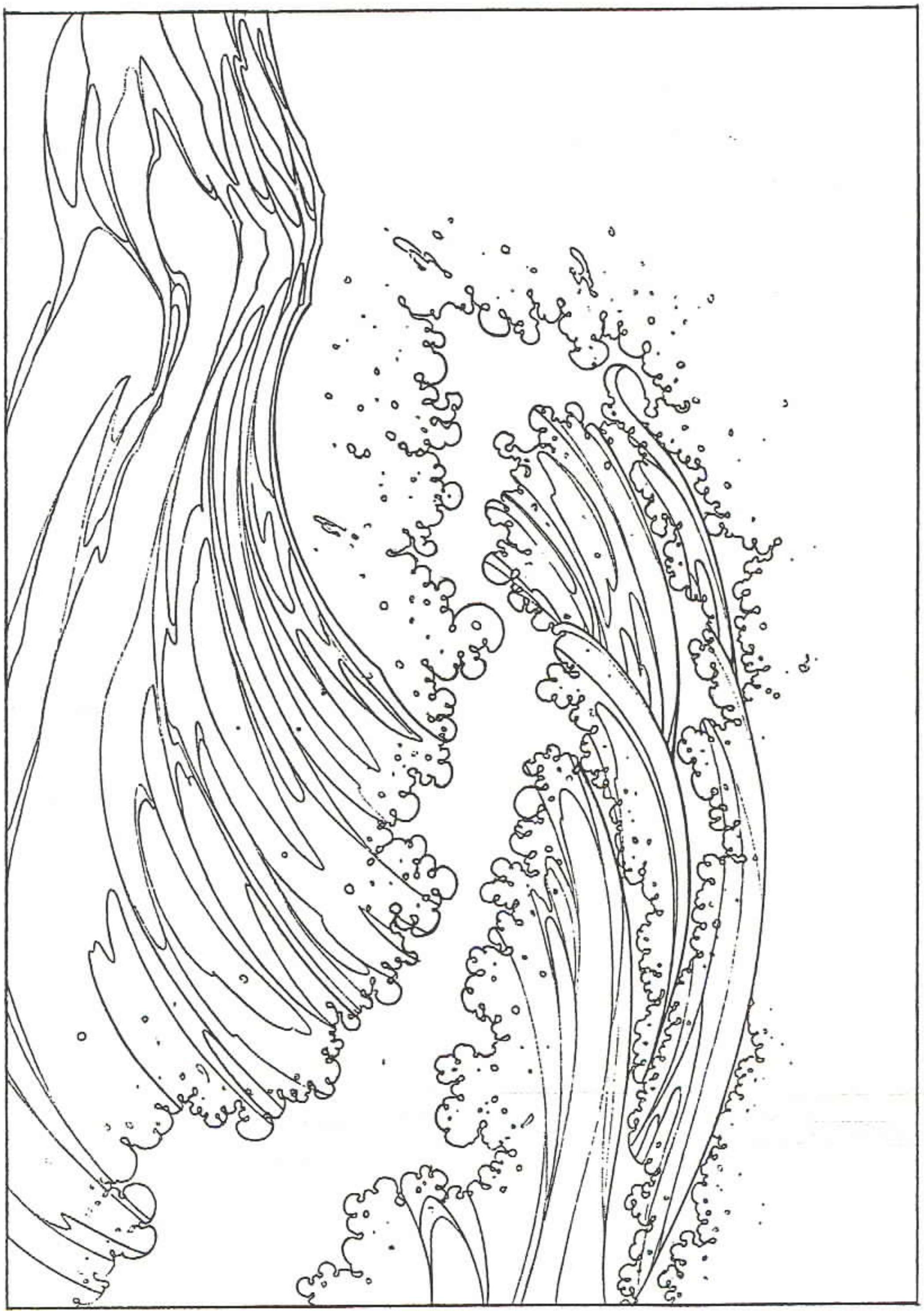
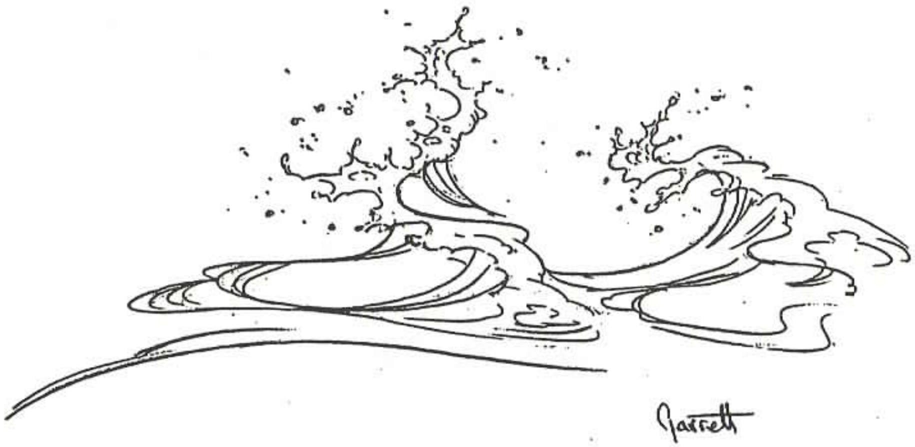



Garrett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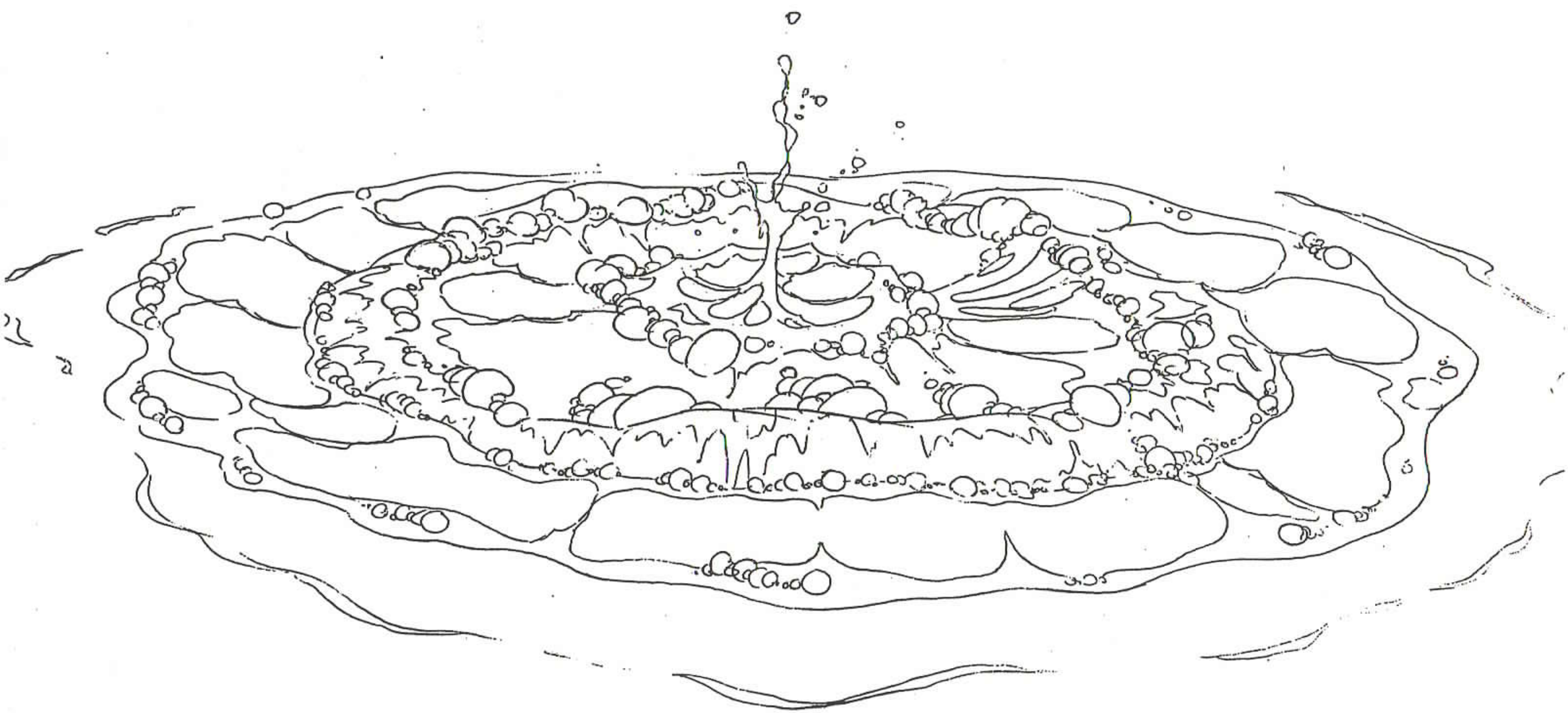

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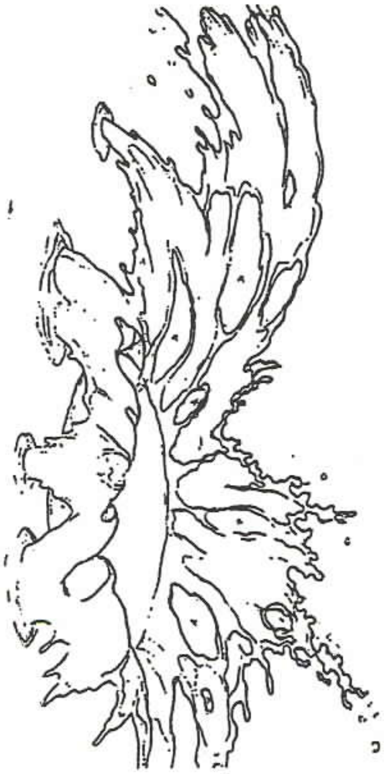
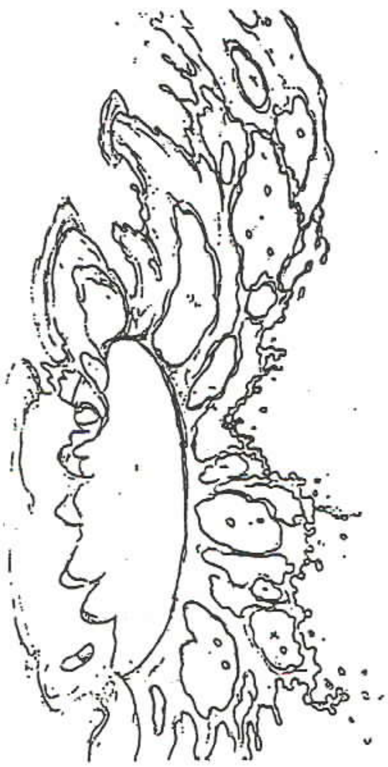
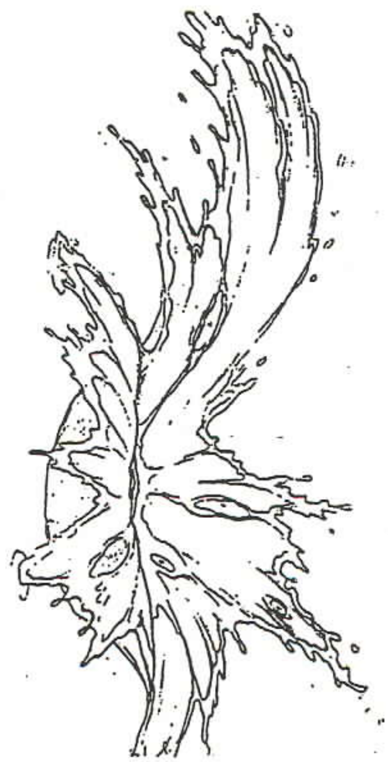
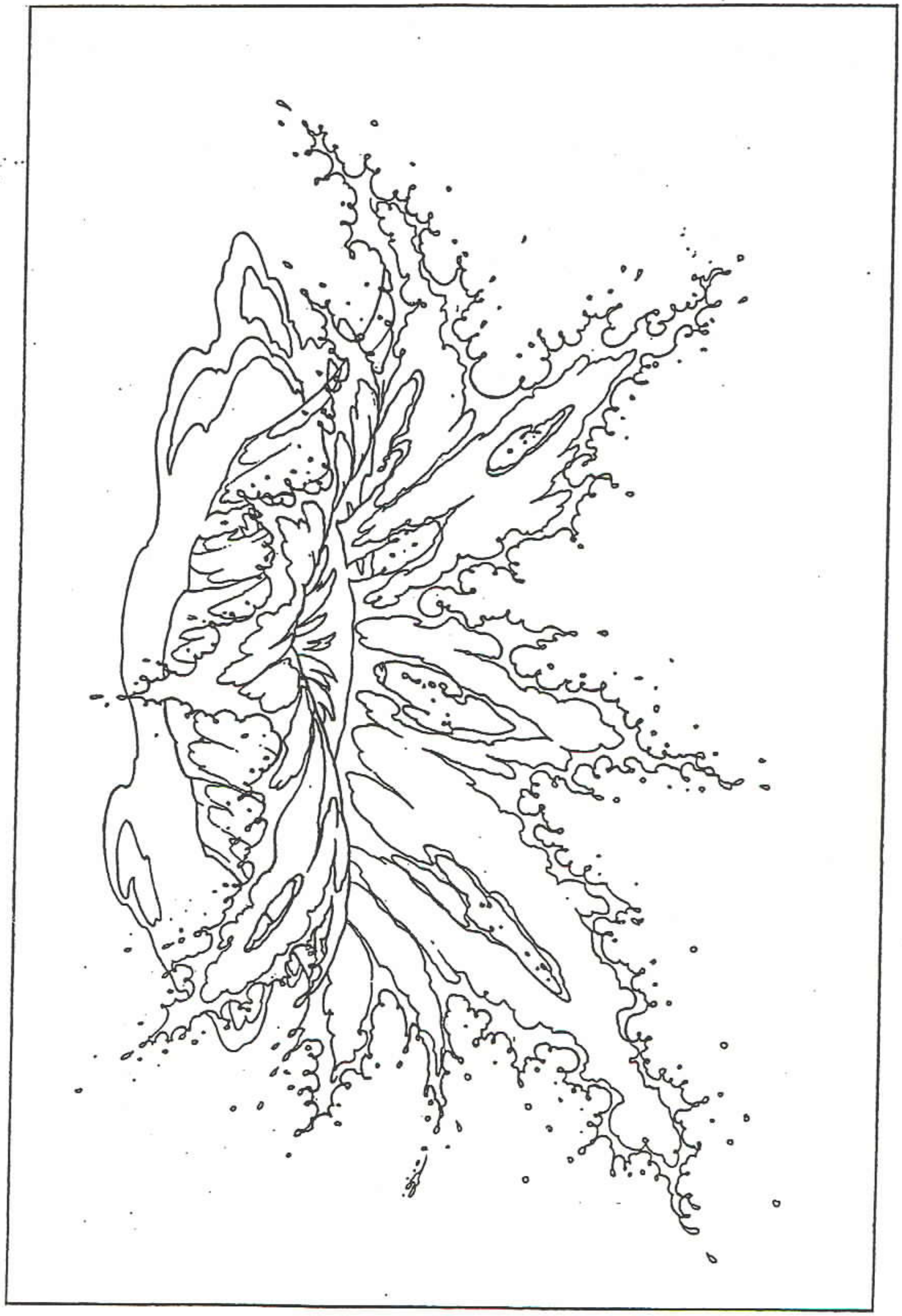
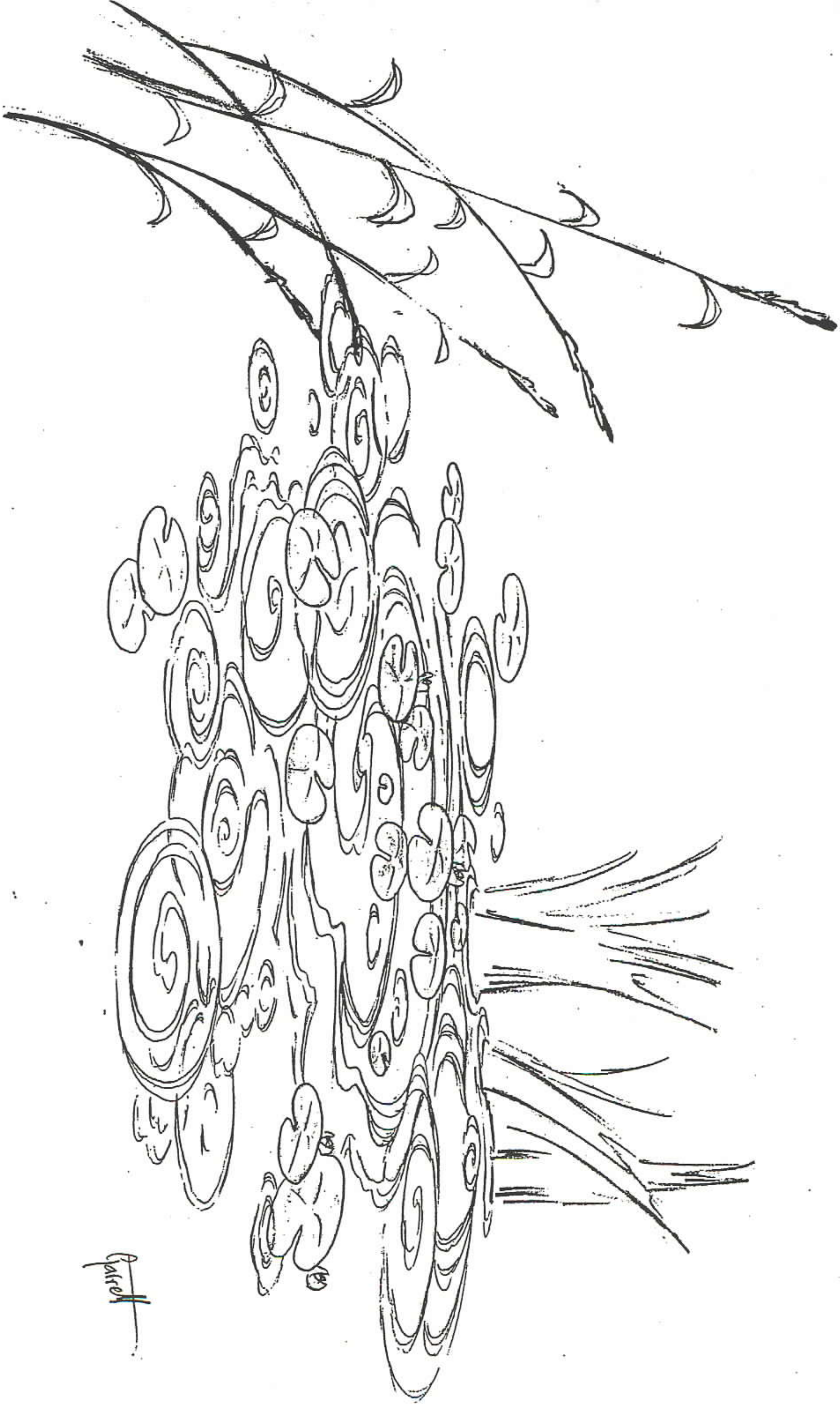
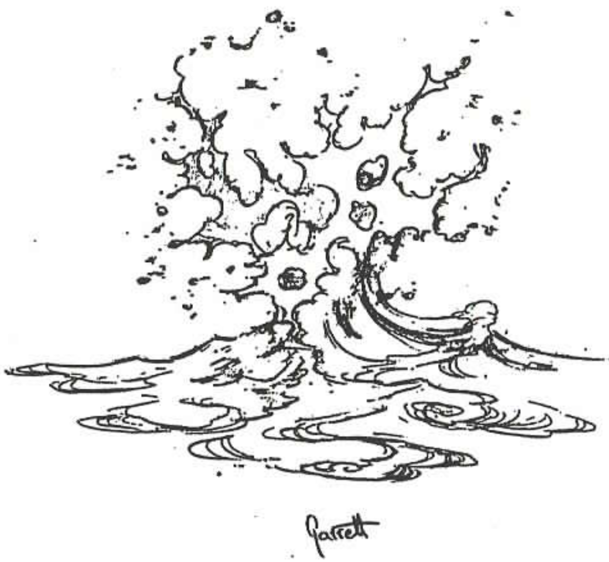





Jarrett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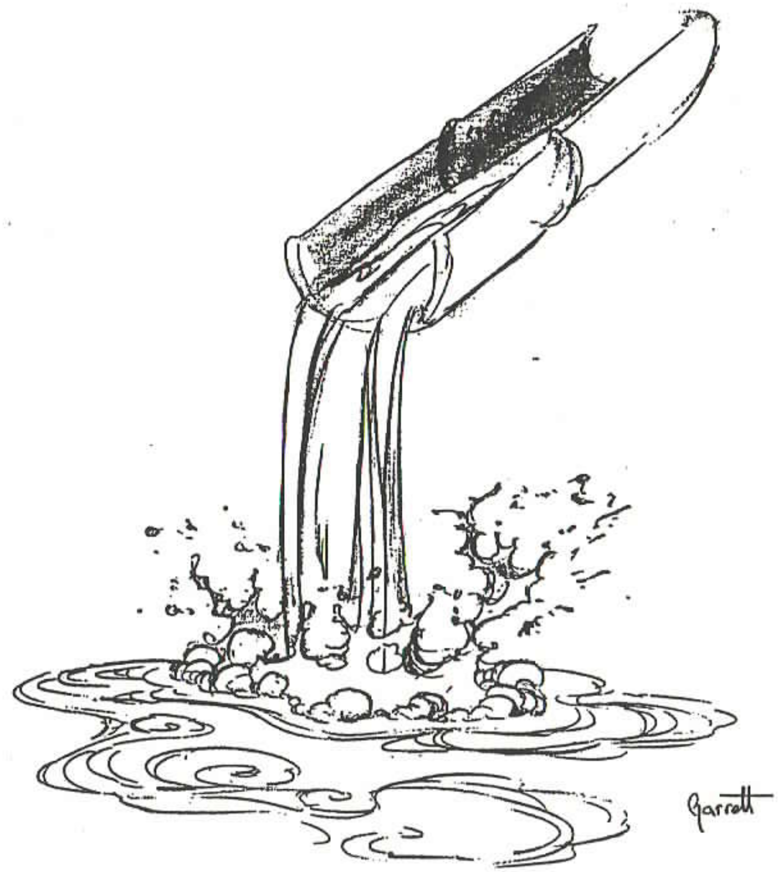
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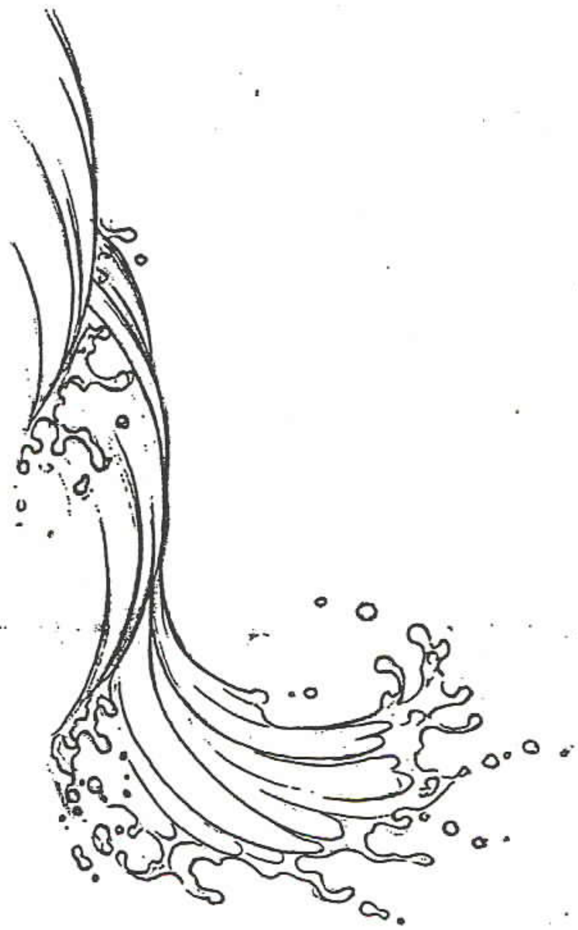
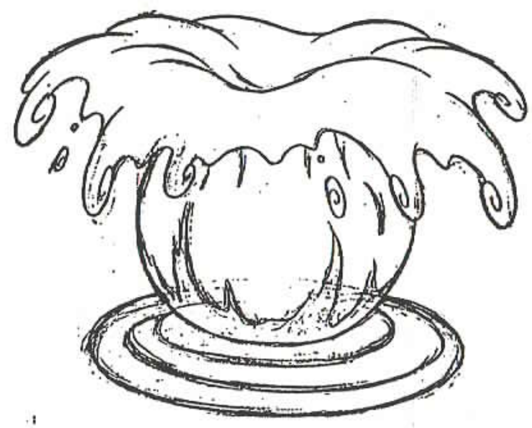
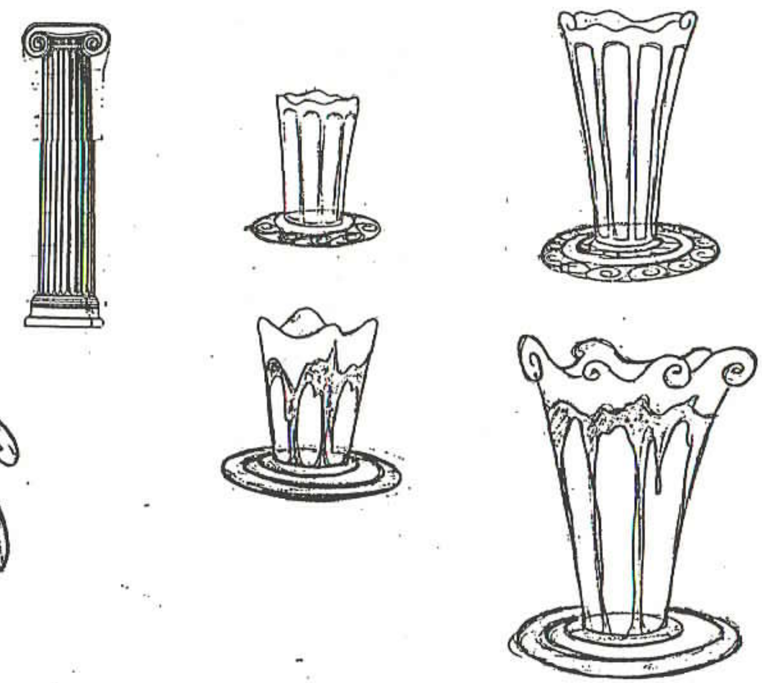


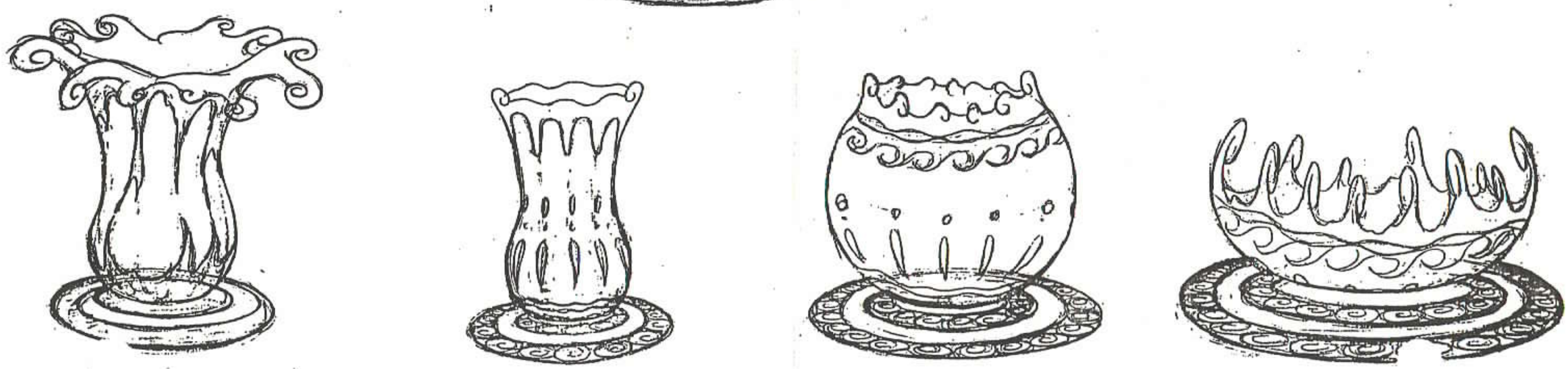
HERCULES

EFFECTS DESIGN

* DESIGN APPROACH FOR SMALL SCALE "REAL WORLD" SPLASHES







GREEK SPLASHES

VASE BASED CONSTRUCTION
WORKS WITH NEXT PAGE

ANIMATION TIMING

FRAME 1

FRAME 3

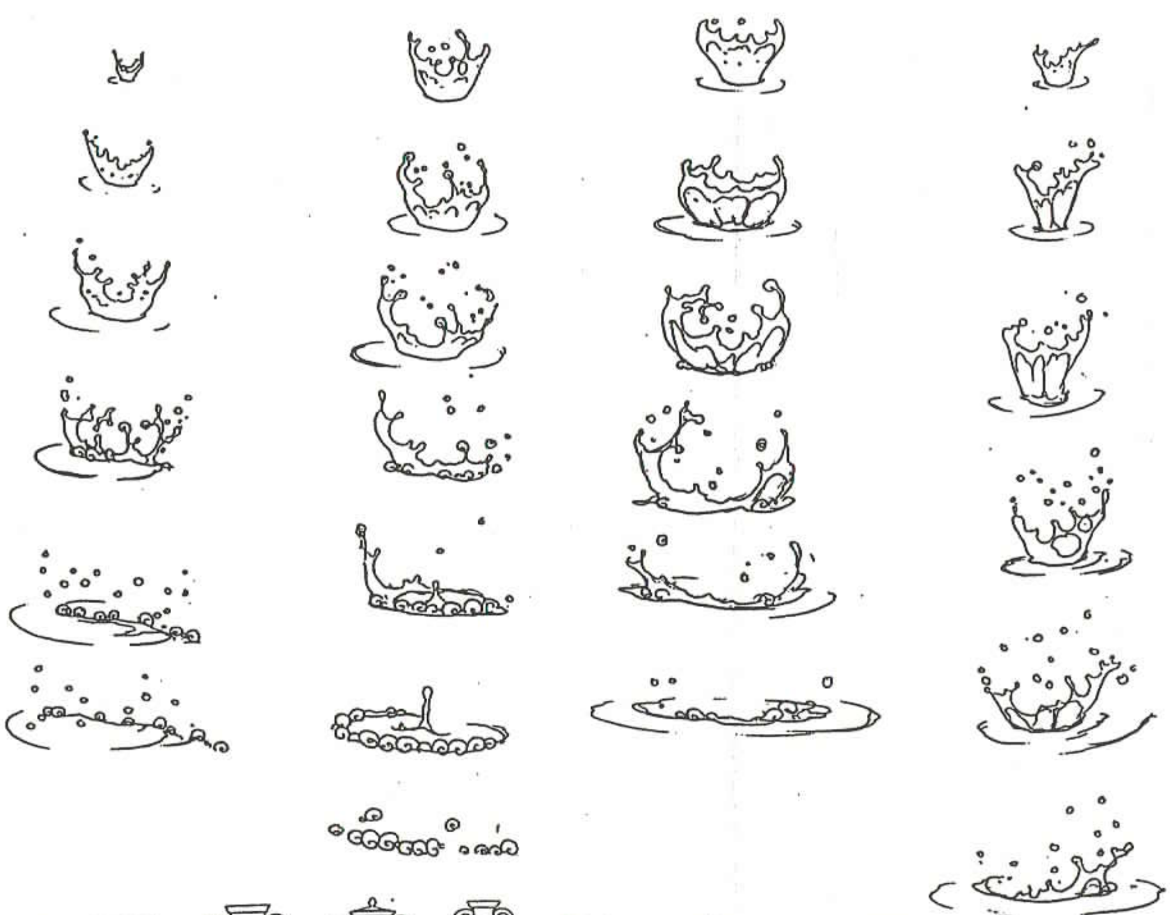
FRAME 5

FRAME 7

FRAME 9

FRAME 11

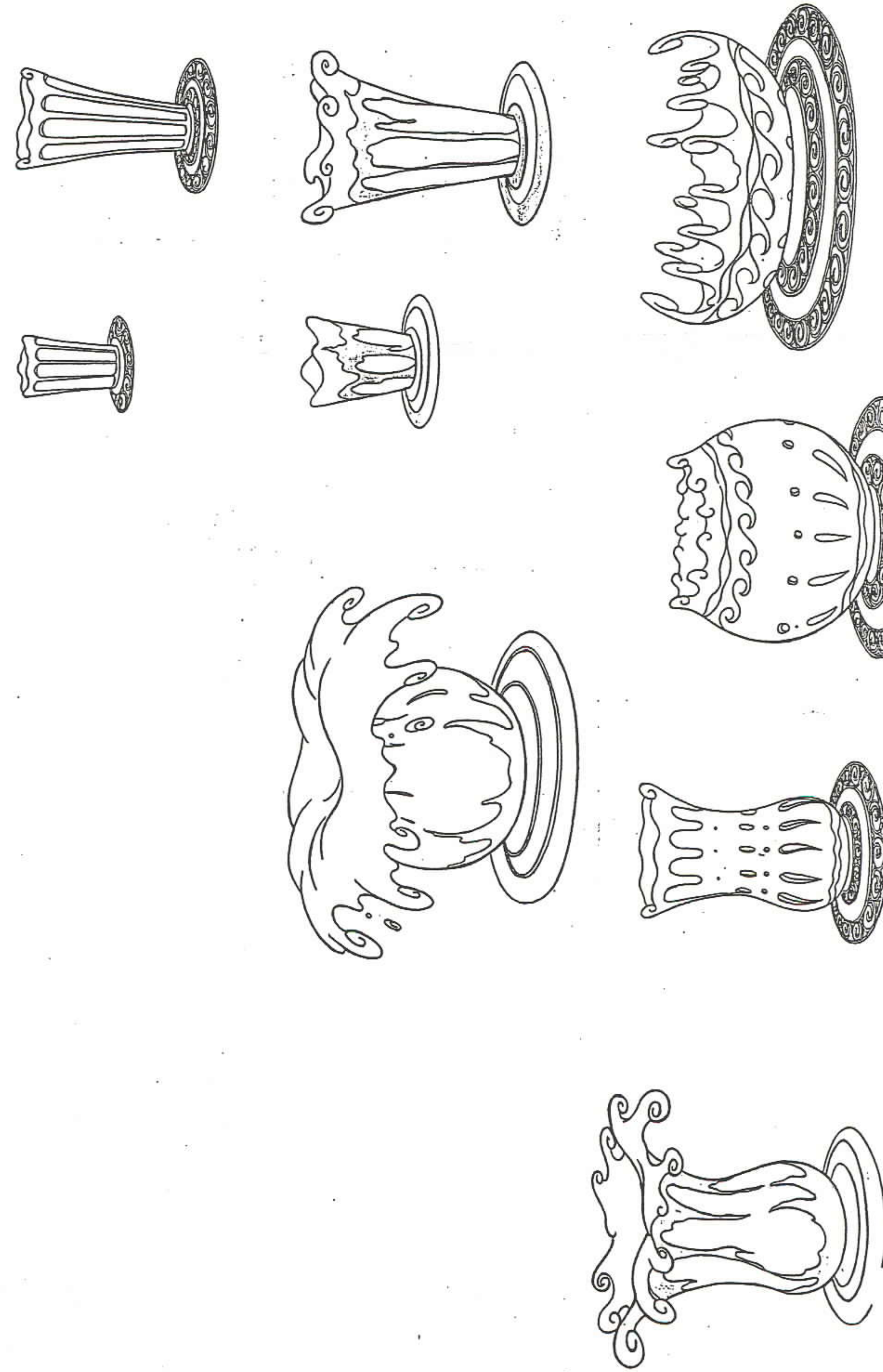
FRAME 13

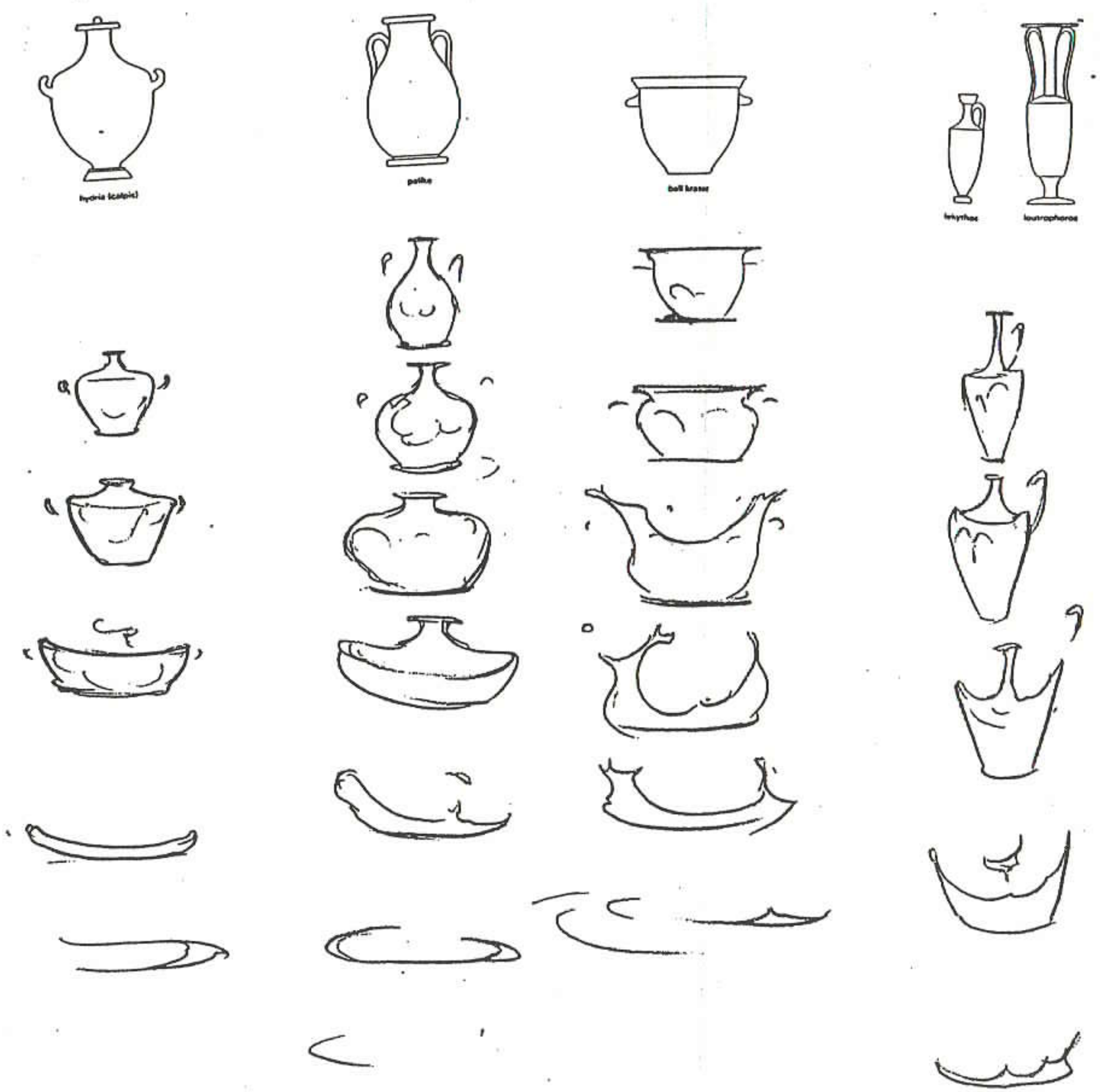


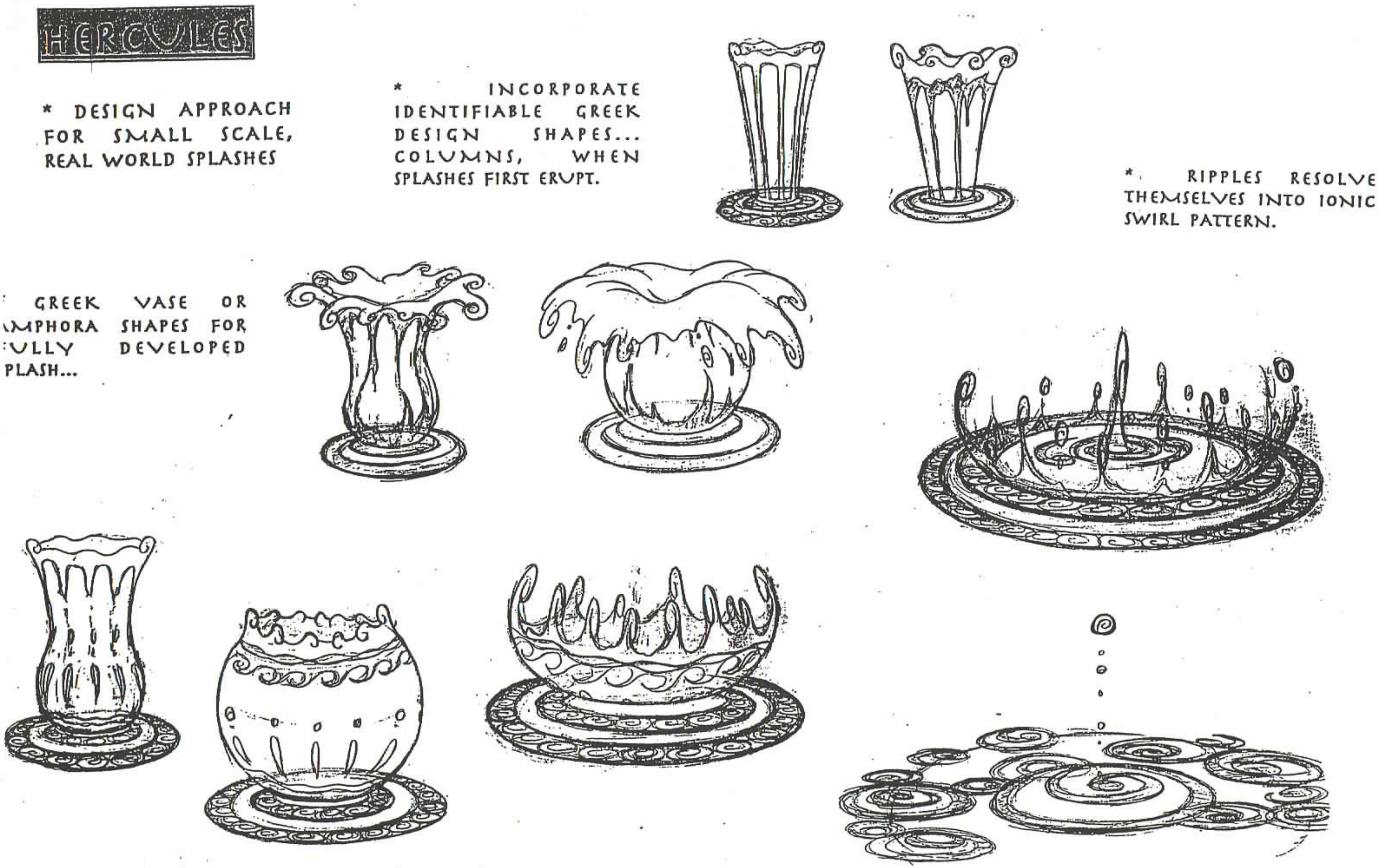
* THESE THESE ARE ACTUAL ANIMATION DRAWINGS.

* THIS TIMING WORKS FOR SMALL DROPS - FAST; NO EXAGERATED "LINGER": QUICK DISSAPATION.

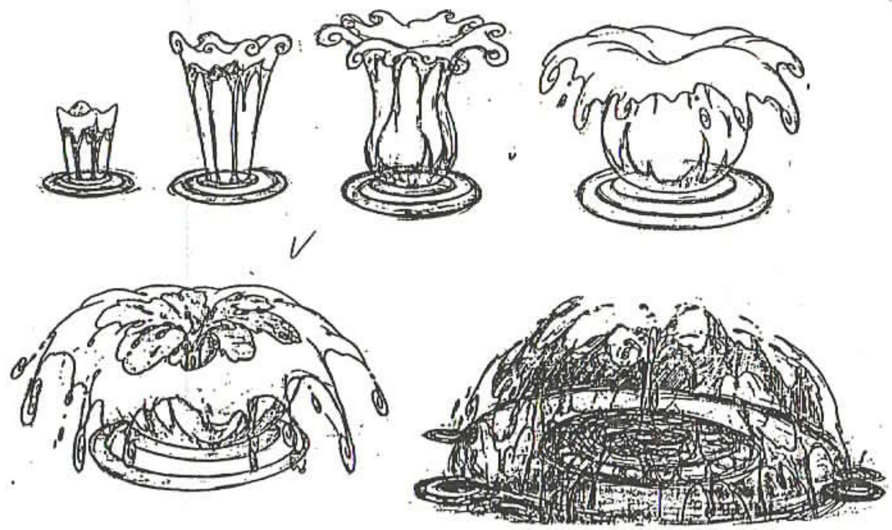
* THREE DRAWINGS DEFINE UP", AND THREE DRAWINGS DEFINE "DOWN"



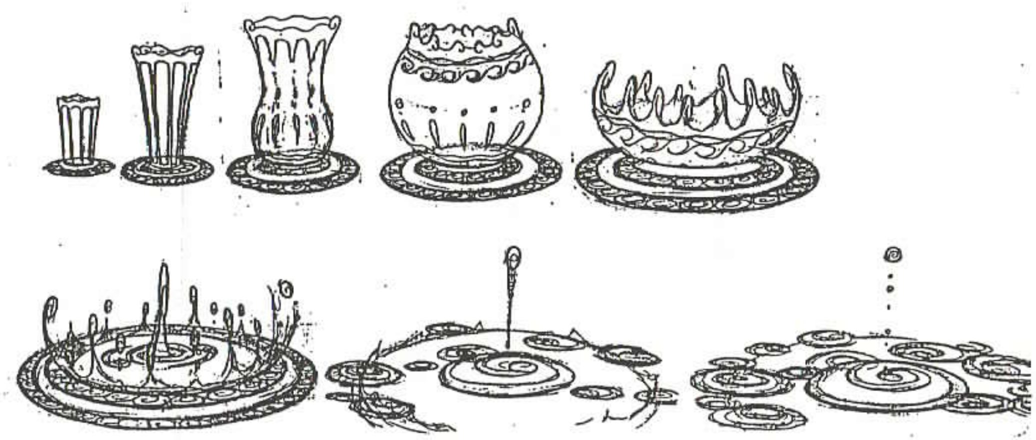

hydria (kalpis)
pelike
bell krater
lekythos
loutrophoros


HERCULES
* DESIGN APPROACH FOR SMALL SCALE, REAL WORLD SPLASHES
* INCORPORATE IDENTIFIABLE GREEK DESIGN SHAPES... COLUMNS, WHEN SPLASHES FIRST ERUPT.
* RIPPLES RESOLVE THEMSELVES INTO IONIC SWIRL PATTERN.
GREEK VASE OR AMPHORA SHAPES FOR FULLY DEVELOPED SPLASH...

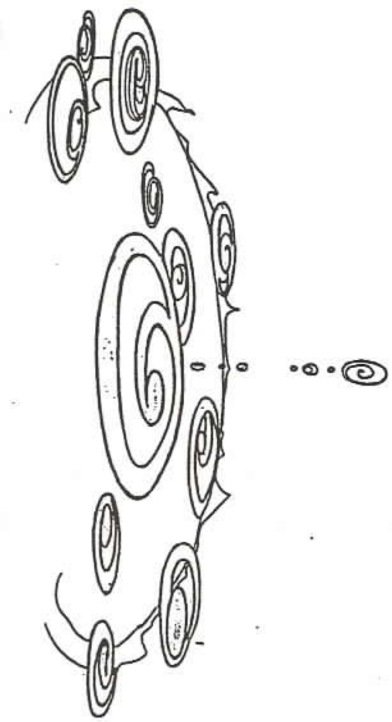
TWO SPLASH SEQUENCES

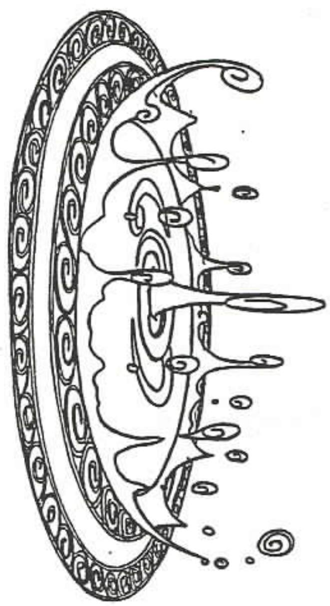


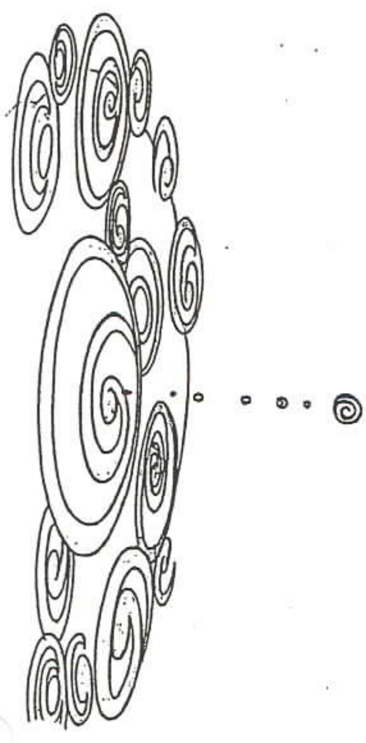
* MORE STYLIZED, WITH READILY RECOGNIZABLE DESIGN ELEMENTS...

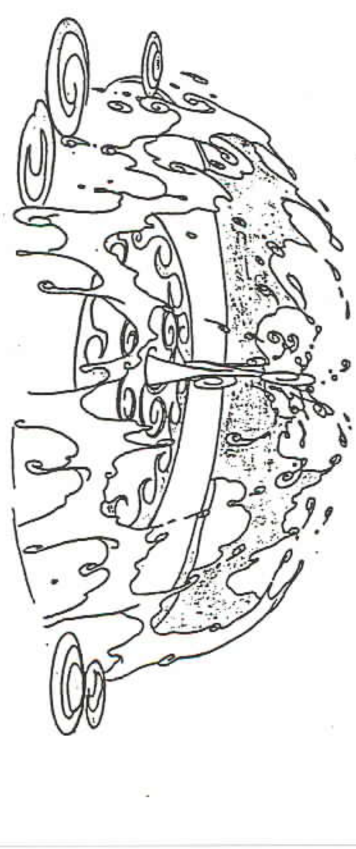


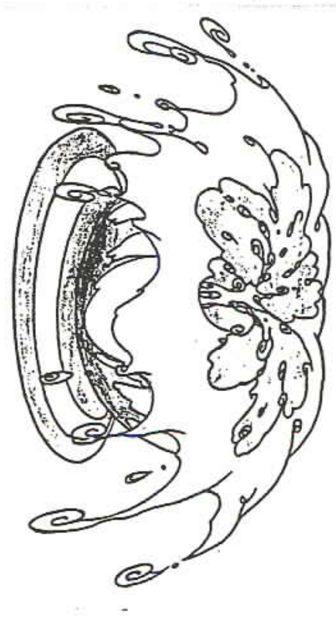
* MORE ORGANIC SPLASH, WITH MORE SUBTLY INTEGRATED GREEK DESIGN MOTIFS...









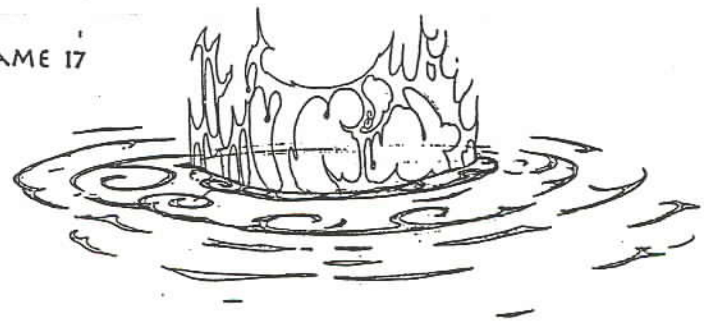


APPROVED RIPPLE ANIMATION

FRAME 1

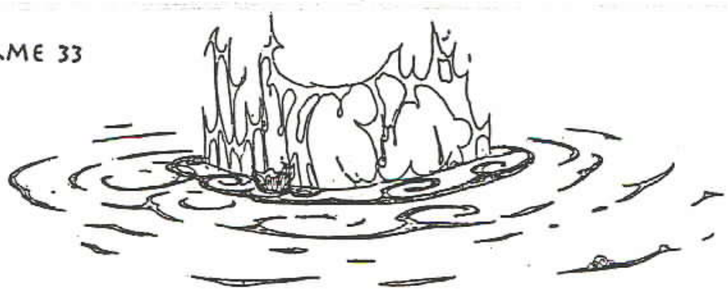
* AFTER THE DESIGN WAS APPROVED: I STARTED ANIMATION BY SKETCHING OUT THE KEY FRAME RIPPLES AND DRIPS IN <u>ONE FOOT</u> INCREMENTS.

FRAME 17



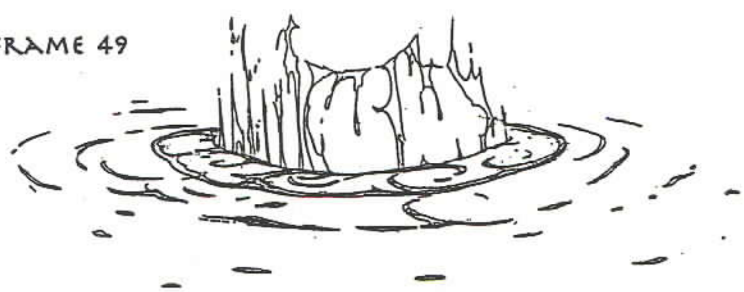
* AFTER DOING BREAKDOWNS, I REFINED THE DETAILS AND REALLY GOT THE ANIMATION FLOWING ON 8'S AND 4'S.

FRAME 33



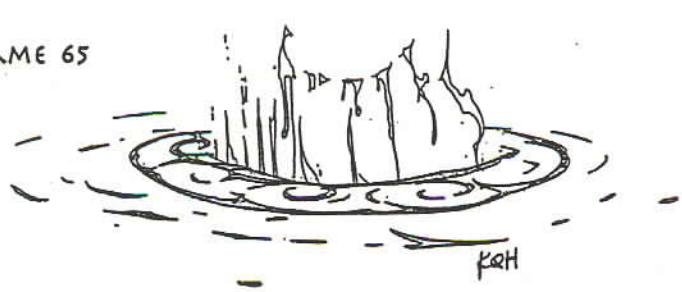
* THE SPLASHES WERE ADDED STRAIGHT AHEAD ON 2'S.

FRAME 49



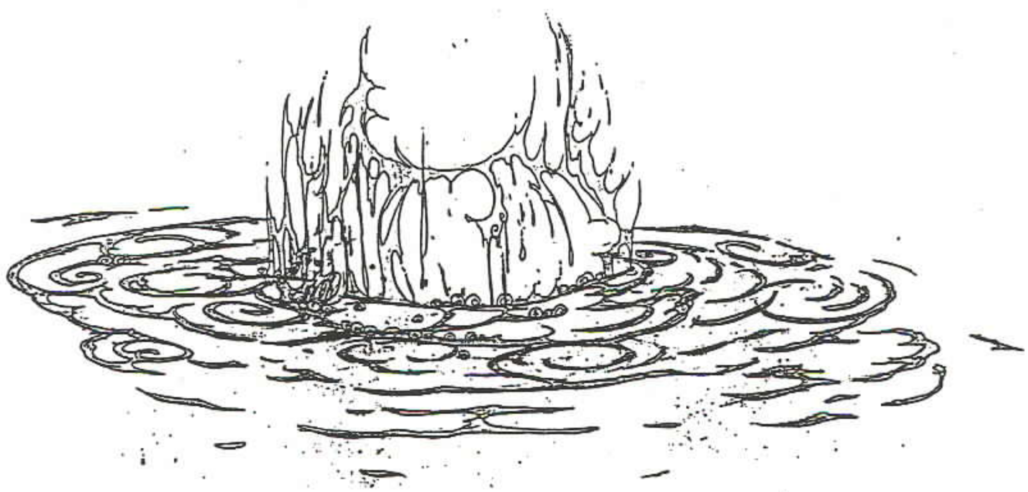
* NOTE IONIC SWIRLS.

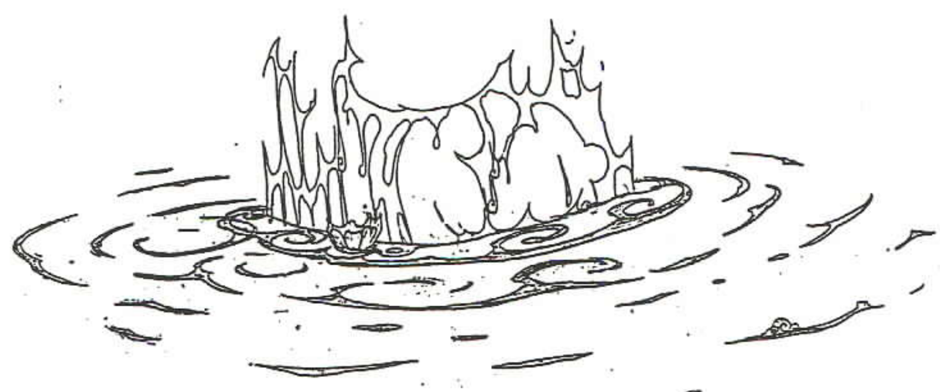
FRAME 65



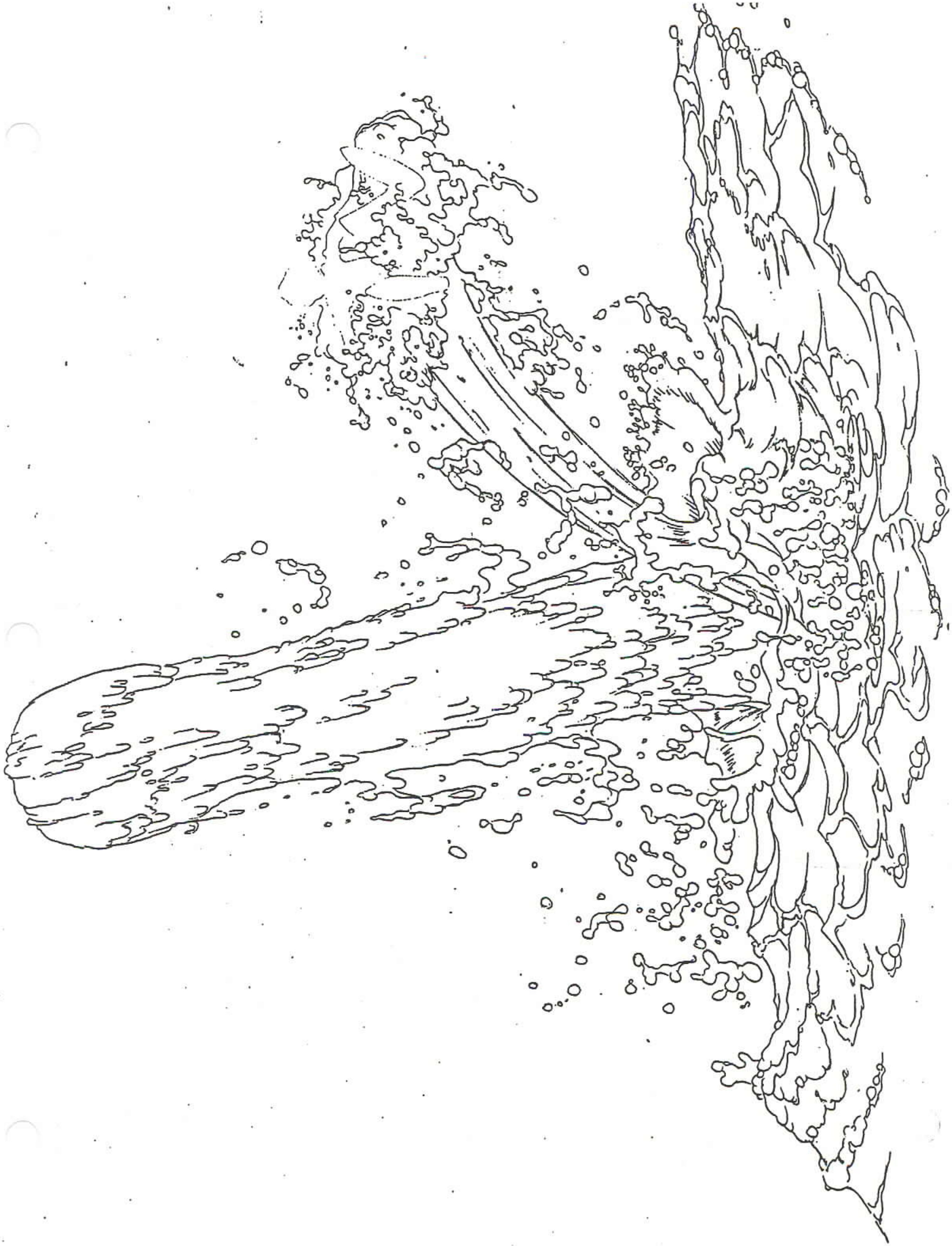
* ACTION IS SMOOTH AND SLOW.

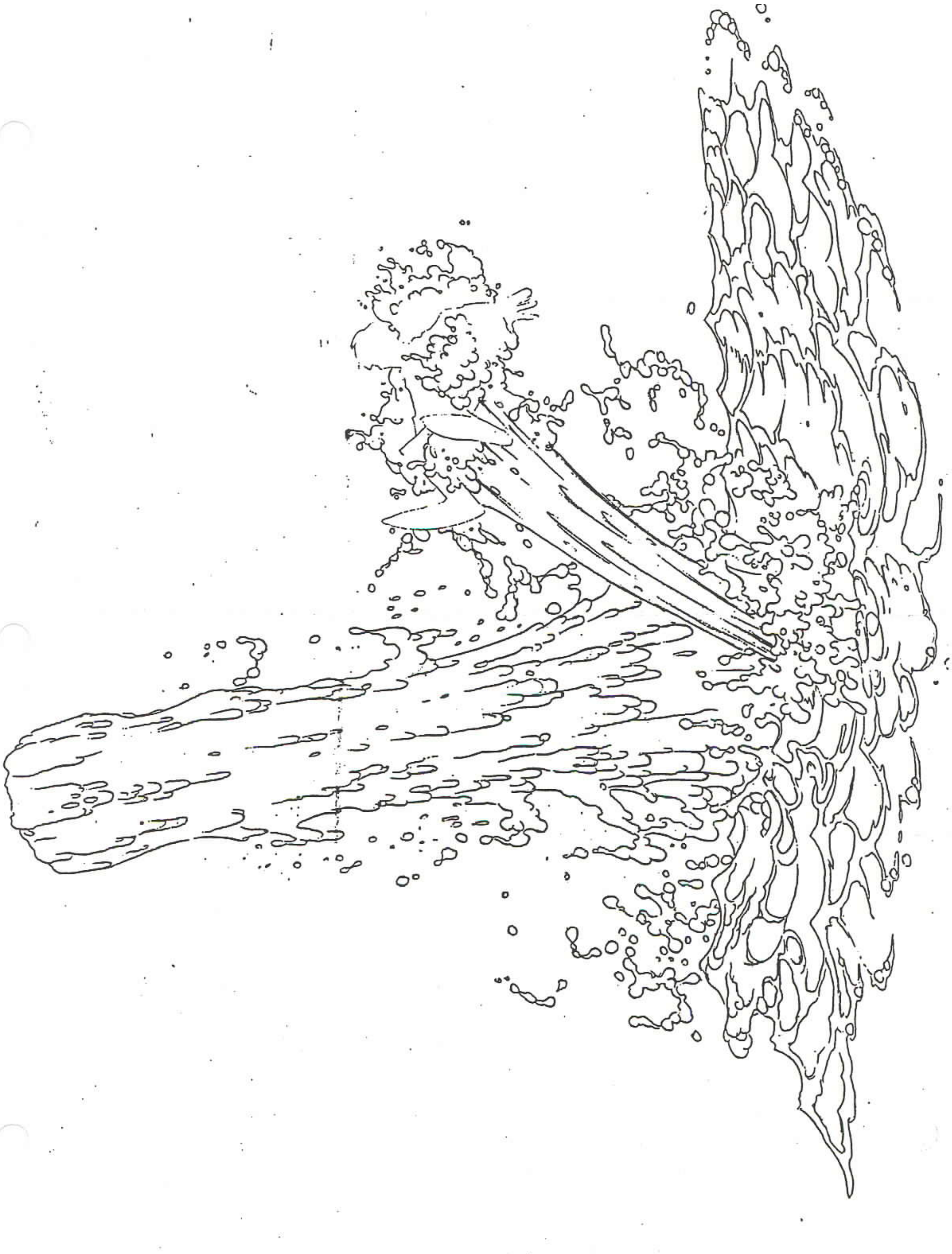
* DON'T GO THIS WAY; OVERLY COMPLICATED TRANSLATION. NG VERSION. KEEP IT SIMPLE!

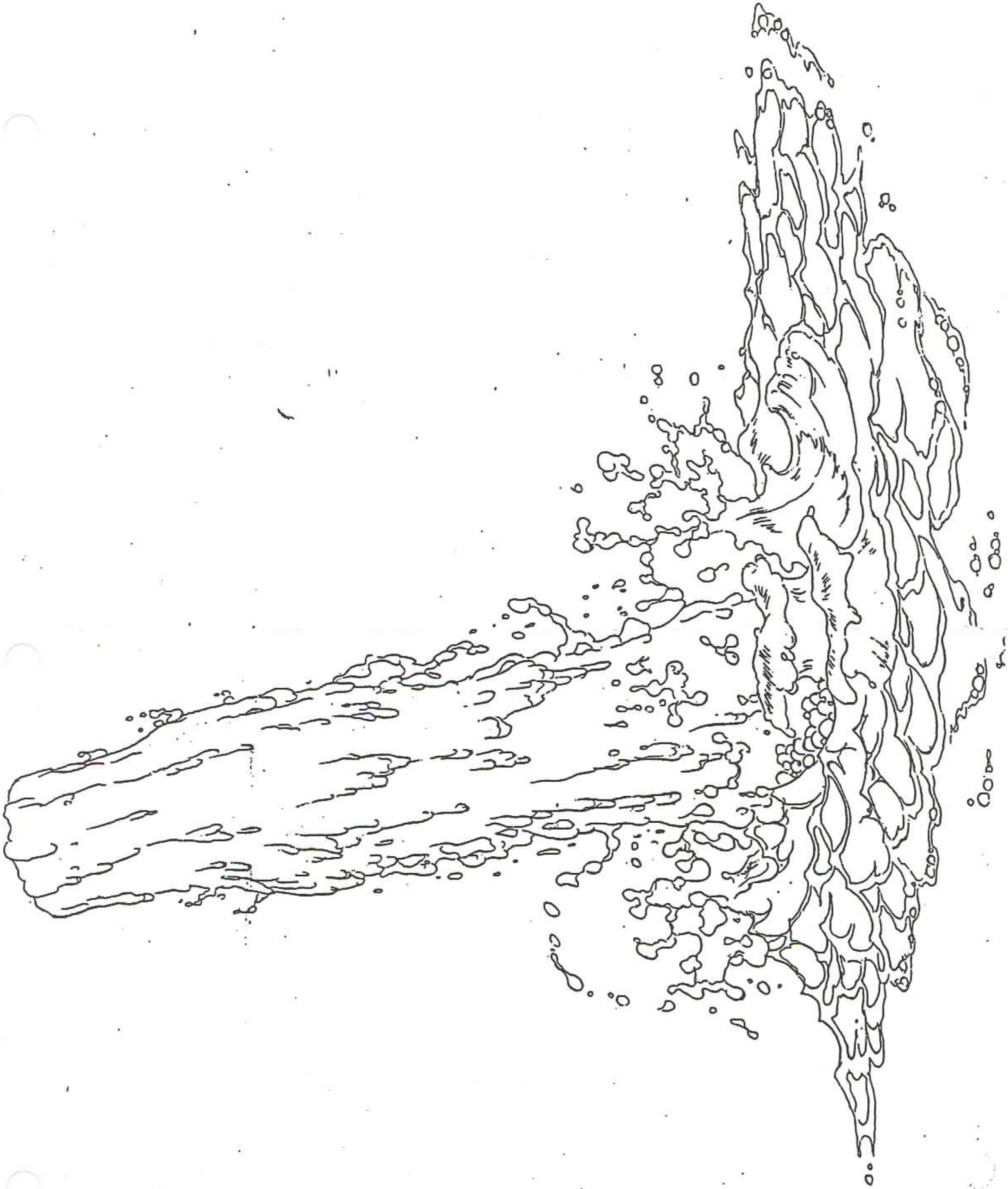


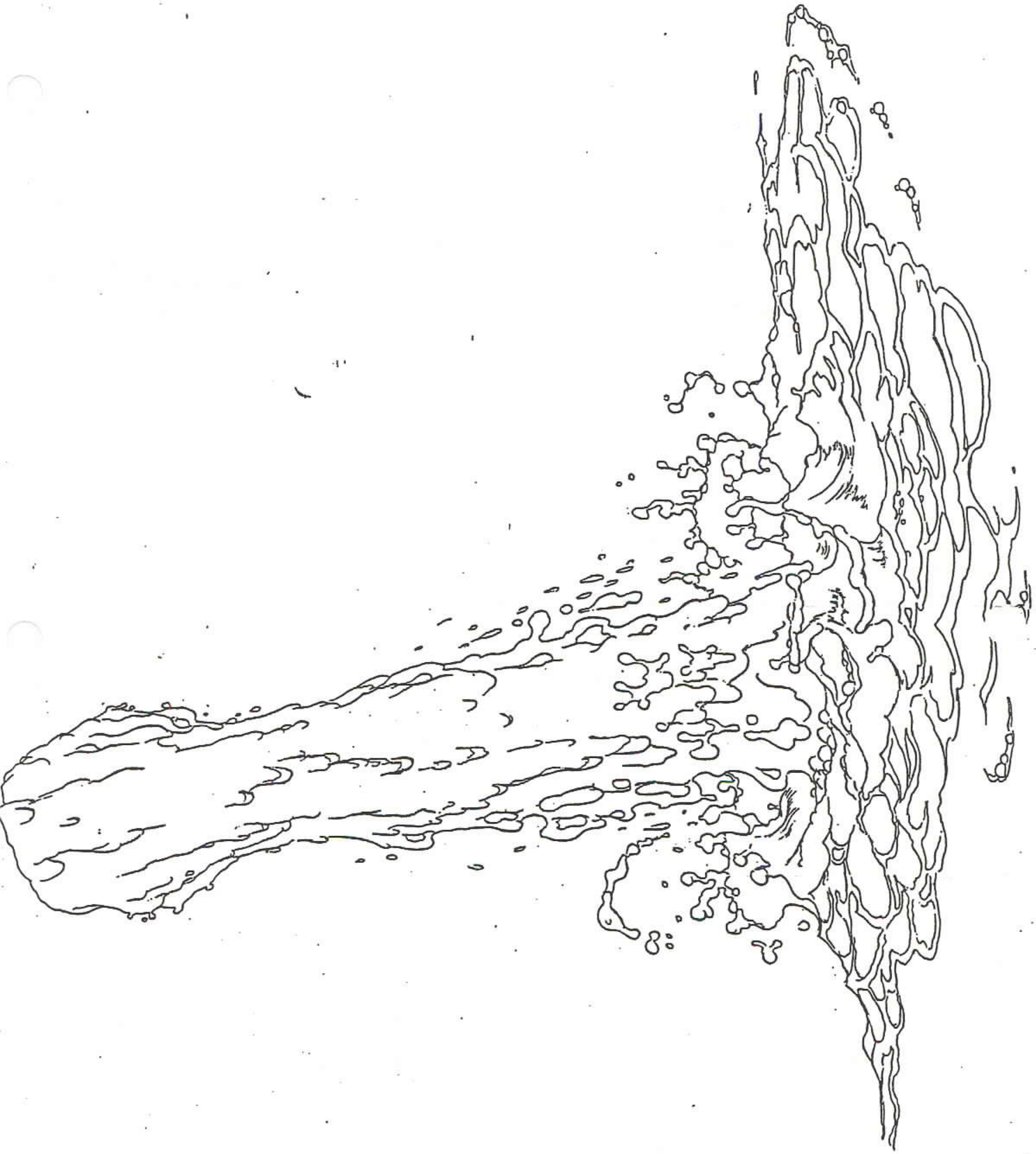


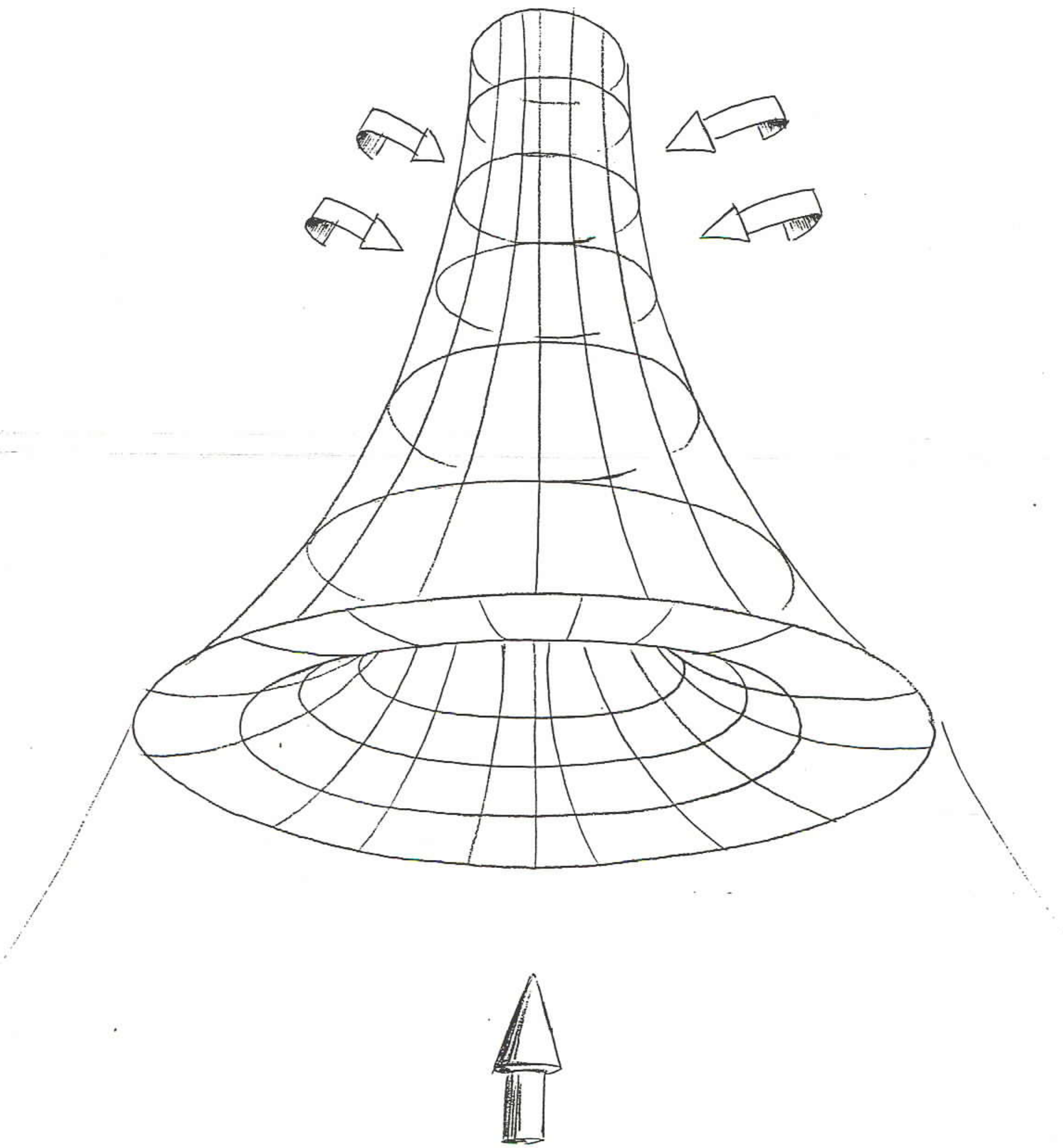

KQH

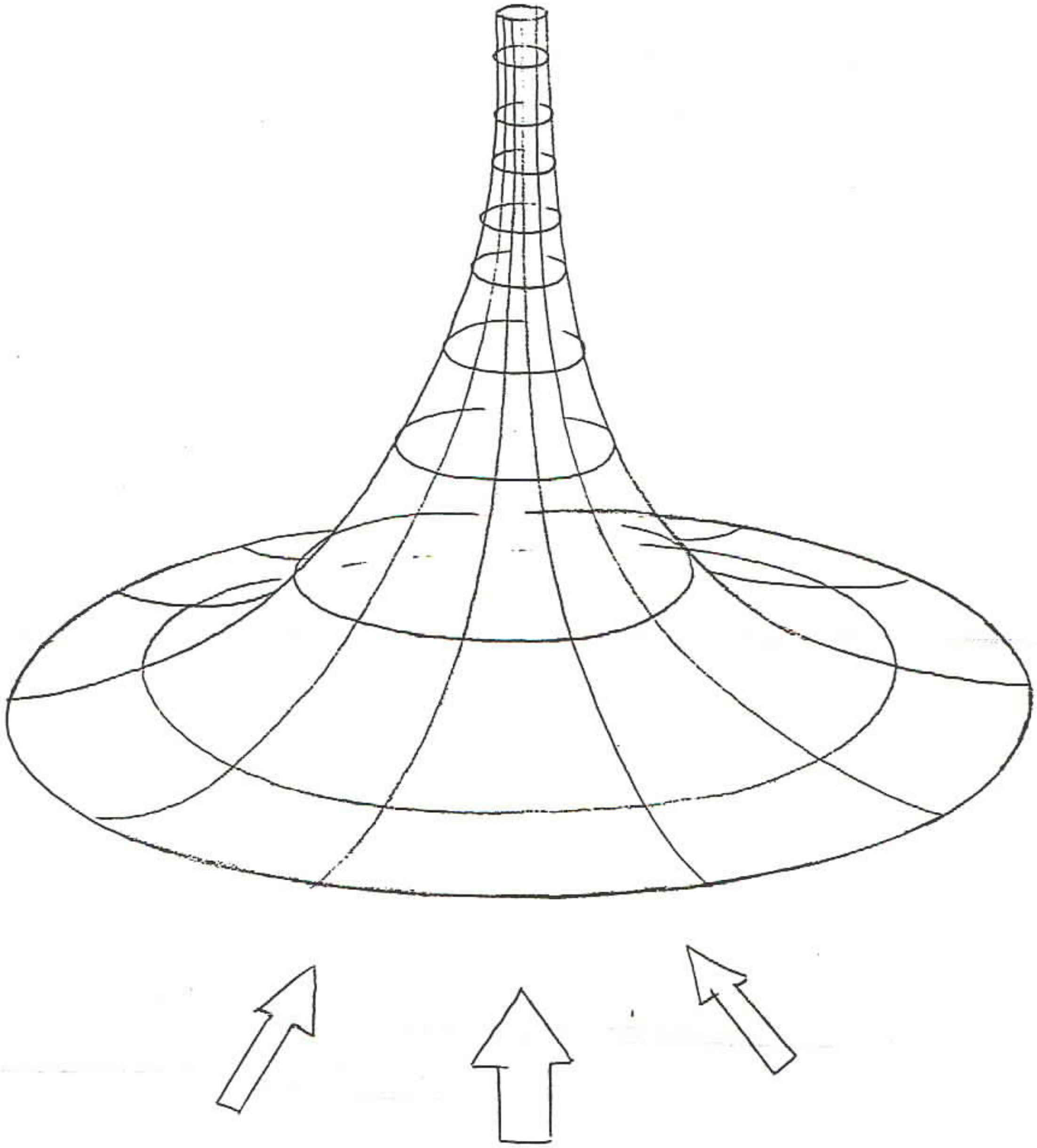


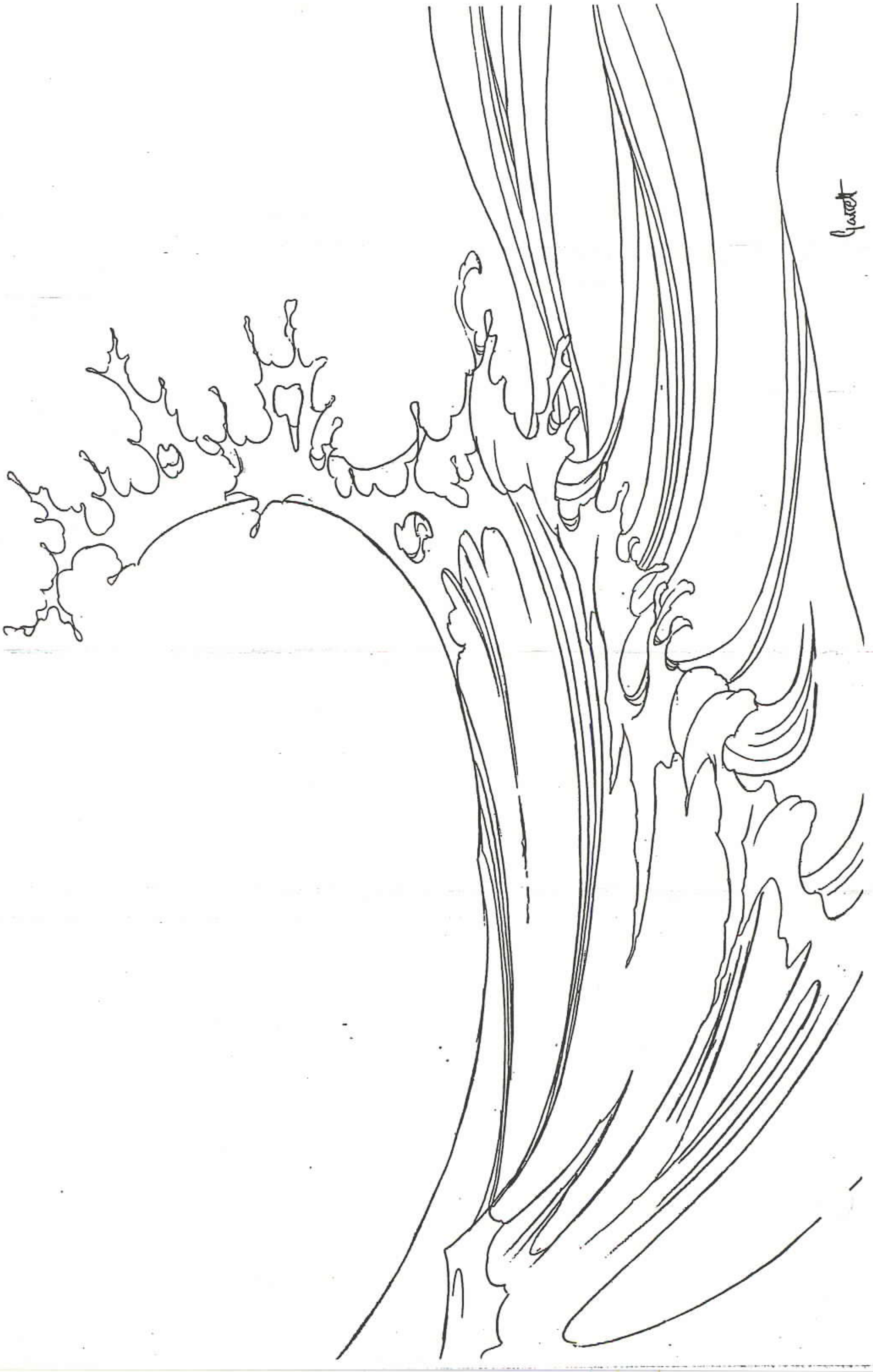








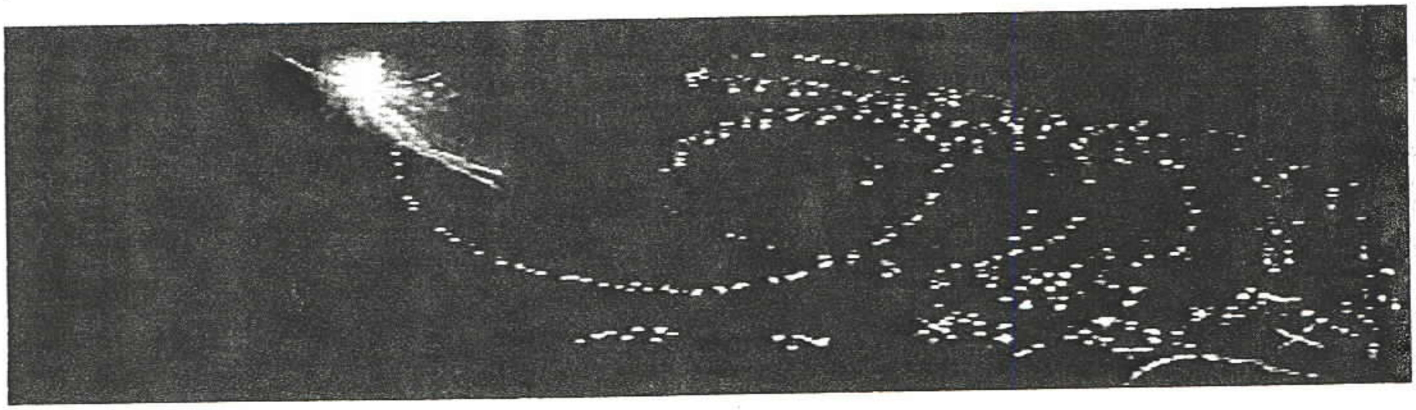



Garrett


Garrett

Standard Pixie-dust

The standards for pixie-dust animation were established many decades ago, with the magic of the Nutcracker Suite in Fantasia. There are varying degrees of complexity of design from scene to scene, but the basic principles remain the same. (show fantasia excerpt) A trail of sparkles are left behind by the fairy's path of action, which then fall slowly downward, twinkling and dissipating slowly as they fall. Twinkles which dissipate very quickly tend to have a more whimsical feeling, twinkles lasting a longer time appear to be a little more serious and intense. A certain amount of gravity, and some centrifugal force come into play, as a magic wand swept in an arc will cause some of the pixie-dust to shoot outwards, widening it's arc before it begins to succumb to gravity.



Of course the true classic pixie-dust has to be Tinkerbell's in Peter Pan, and it is worthwhile to take the time to analyze how it was done no matter what kind of pixie-dust you may be attempting. In any case, unlike fire or water, there is no live action reference for pixie-dust. You can research and analyze animated pixie-dust from countless animated films produced in the last 50 years.

When animating pixie-dust, it is common to animate 'straight ahead' on two's or maybe fours. In-betweening pixie-dust is one of the most painstaking and time consuming chores known to man, and personally I wouldn't wish it on anyone, so I try to animate the stuff straight ahead with no follow up work. If you find yourself in-betweening pixie-dust, hang in there, someone's got to do it, and the results can be beautiful if it is well done!

Exposures, Glows and Star-filters.

With the advances in digital imagery in the last decade, much of what was standard industry procedure has changed completely, and the changes have been good and bad for the effects animator. In the "old days" when animation cameras with actual film in them were still being used, a technique called "backlit" animation was relied upon heavily for magical special effects. The idea was that if you shine light through a pinhole in a piece of black paper, by then varying the f-stop or shutter speed of the camera and using star-filters and/or diffusion filters, a staggering number of very beautiful effects could be accomplished with even just a simple [illegible] In today's digital world, these effects can

Exposures, Glows and Star-filters.

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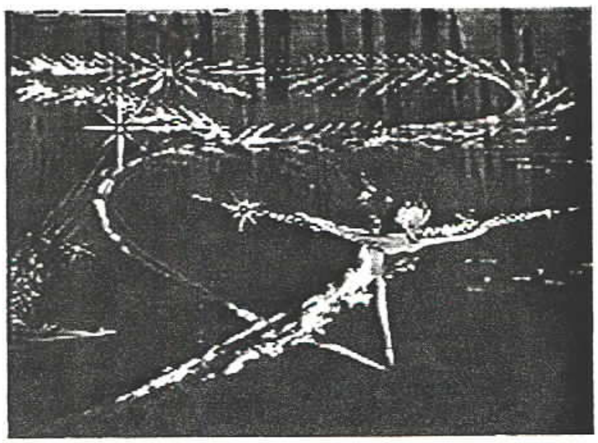
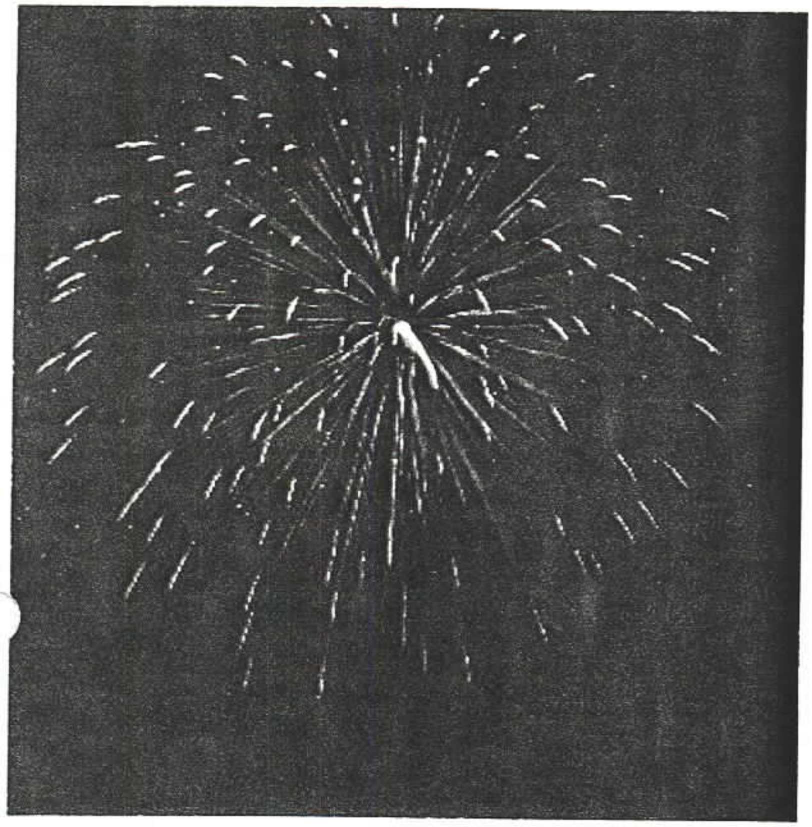


There is a beautiful twist on the standard pixie-dust effect in Fantasia, when the fairies in the Nutcracker Suite skate on the ice, leaving behind fantastic frost patterns which freeze into a fixed final position rather than trailing off slowly. Gorgeous stuff!

In virtually every Disney Feature, and especially the fairy tales, you can find some special effects which can be described as "magic". The Sorcerer's magic in the Sorcerer's Apprentice, Cinderella's transformation, the Beast's transformation in Beauty and the Beast, Ursula's conjuring in The Little Mermaid, countless magical transformations of the Genie in Aladdin, (in which case there was a very fine line between the character and f.x. animation) and the smoke visions in Pocahontas which took a more traditional smoke and fire effect, and pushed it into a 'magical' effect. The possibilities will always be limitless, and the Disney f.x. crew will always be called upon to take on new and exciting challenges.

Electricity, lightening, sparks and fireworks

Although not really falling into the Magic category, these effects are very closely related to magical pixie-dust, and so I have included them here.



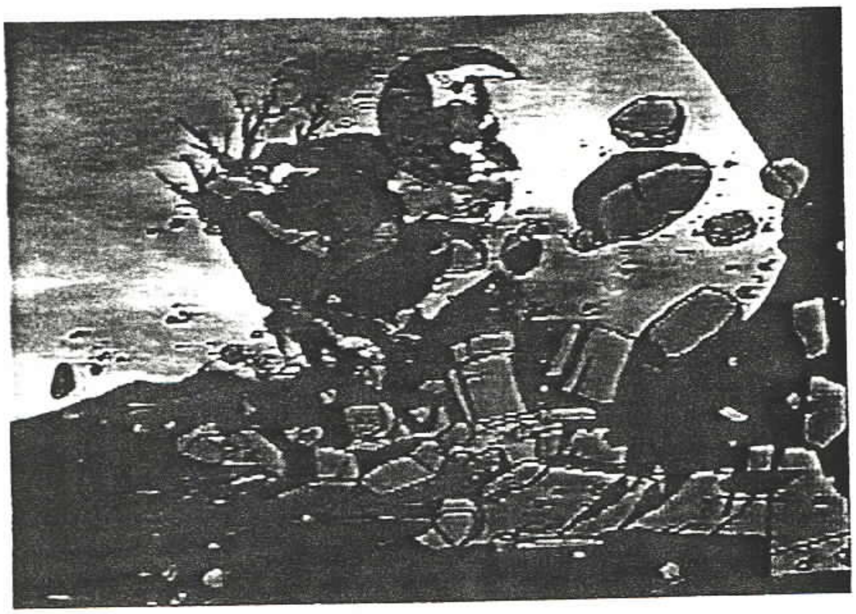
Fireworks are really just an attempt to create magic in the sky and are very similar to pixie-dust f.x., and sparks can behave in much the same manner as well. Sparks can be little star-like shapes which shoot out from a point of friction, or from whatever else may be generating them. They only last a very short time, somewhere between 4 and 12 frames, before they have petered out. Fire-works generally radiate straight out from a center explosion, and then they are slowly dragged down by gravity as they finally dissipate. A typical fireworks blast could last from 2 or 3 seconds, up to 8 to 12 seconds, depending on the desired effect.

Lightening and electricity are of course one in the same, lightening simply being electricity on a really big scale. The basic shapes involved are usually jagged lines of white light created by the electricity arcing from one object to another. We know that lightening does not actually leap from a cloud to the ground, but travels from the ground up, and in most cases lightening bolts or smaller electrical arcs should be drawn as simply bridging the gap, and not animating from one point to another. (The same is true when animating laser beams) Under careful scrutiny of photos of lightening, it is interesting to note that the jagged shapes are actually slightly rounded, and it is good to keep that in mind. There has been a lot of special f.x. lightening and electricity in both live action films and animated films, and it is surprising to see how often it is poorly done. With all the live action references available to us today, there is no excuse to do it badly. Study and research the shapes thoroughly, and you should be able to come up with something that looks very convincing.

In many cases we may not see the actual bolt of lightening, but we will just see the extreme highlights and shadows created by the blinding flash of light. In many cases, some variations of describing both the lightening bolt and the lighting effects that it creates, will be incorporated into the same scene. As always with effects animation, preliminary research and experimentation will bring the best results.

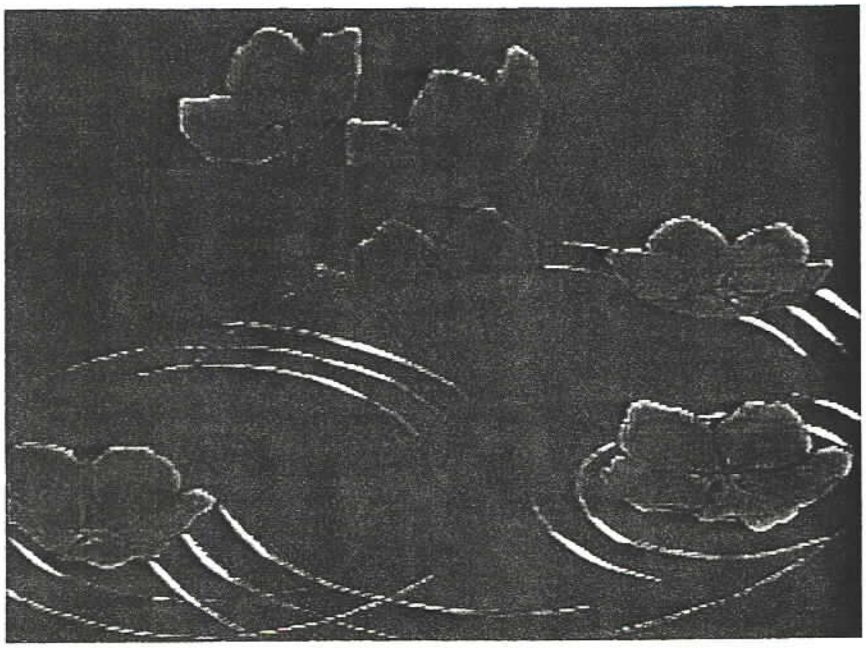
2) Breaking Objects

Just about any substance known to man can be broken or destroyed in some manner, and if it can be broken, we will probably eventually be called upon to break it. Glass, rocks, ice, snow, dirt, wood, a chocolate cake, butter, cars, a pumpkin, plates, cups, a box of laundry detergent, bricks, buildings and boulders, are just a few of the things I've run across personally. The best way to understand how things break, of course, is to break them, and again, we start our research very young. The rate at which a given object breaks and falls, and the patterns and shapes that it creates as it cracks, splits and ultimately falls apart, are all governed by the size, the weight, the density, and all the physical attributes of the given object, such as the grain in a piece of wood, the chalkiness of plaster, the brittleness of shale rock, the pulpiness of a pumpkin, or the crystaline quality of ice. Research with the actual substance is the best bet, and filming it for frame by frame study. Explore the intricate and sometimes beautiful shapes created by cracking, splitting and crumbling substances.



This sort of effects animation is closely related to a lot of props animation, such as a breaking dish or glass. A crumbling boulder in an earthquake is indeed a natural prop, and can be approached as a geometrical object, with it's uneven, rock-like qualities added on after the basic shapes and path of action of the object have been determined. Fantastic reference can be found everywhere, and violent live-action films are a treasure trove of this type of effects reference.

3) Floating and Falling objects



The most closely related to our pixie-dust animation, is animating a variety of falling objects of varying weights and densities. This could be virtually anything, but most difficult and intriguing are light-weight objects which are aerodynamically affected when falling. This can include feathers, confetti, leaves, flower petals, dandruff, dandelion seeds and other flying seeds, a falling tissue or handkerchief, and etc. etc.

Much like smoke, most of these light weight objects can be affected by air currents and eddies, but as opposed to rising with the heat, they are pulled down by gravity, and their aerodynamic qualities determine their path of action and rate of descent. A seed with a parachute-like feather on it will fall much like a parachute arcing back and forth slowly on it's descent, a feather or leaf shaped object will arc back and forth much more quickly and broadly, due to it's streamlined aerodynamics, coupled with it's light weight. What child has not blown on an old dandelion, or thrown something light up into the air to watch it's intriguing path of descent? We start our special effects referencing very early. If you have to animate something like this, get out there and play with the real stuff! If you can't, live- action or animated reference is your best bet.

When assisting such subject matter, always make sure you understand the animator's intention, the exact path of action, and the level of detail required. (as with any follow-up work)

4) Overlapping Objects

Includes ropes, whips, chains, curtains, clothing, grass, branches and things. All of these objects have similar attributes when put into motion. Overlapping action is very important, as well as determining the pivot point where the object is anchored down. The object may be affected by it's anchor point being moved, like a chain attached to a moving car, or by outside forces such as wind or another object striking it, like a bird landing on a branch in a snowstorm, or a diver bouncing on a diving board. The variations are limitless.

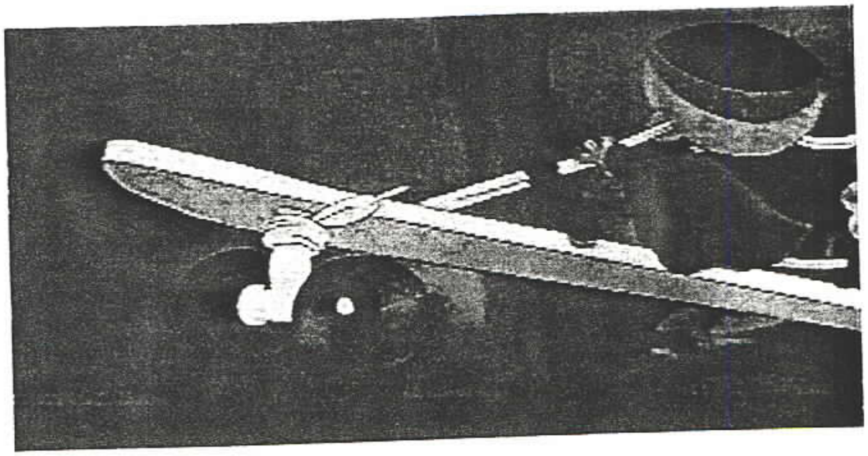
Again the type of movement a given object will assume, is largely a result of it's physical attributes. For any soft, sinewy, easily bendable type of matter, like curtains, drapery, string or rope, the basic flag animation principles come into effect. A continuous overlapping action which moves outward through the object like a wave, starting at the pivot or anchor point and moving out to the end or tip of the object. The size, weight and density of the material, as well as the speed or intensity of the wind or object affecting it, will determine the speed and curvature of it's movement.

In the case of more rigid objects, branches for instance, the pivot point is very important, and another object is more likely to affect it,
although the wind certainly can as well. Without the overlapping wave action of more sinuous materials, these objects will still display overlapping action, as in a branch bouncing up and down after a large, frightened animal has jumped on it, (typical cartoon scenario).

And once again I would recommend experimentation with the actual object whenever possible.

5) All Other Effects

This is a pretty vast and ill defined area of effects animation. It can entail just about the strangest types of artwork imaginable, which when combined in the right way create effects that trick us into seeing something that is not really there. If the wheel of a car is animated to show a slow stretching and squashing action, and then a flashing, slightly blurred reflection is animated in a static position on the circumference of the wheel, we can create the illusion the wheel is spinning, but we have not animated a spinning wheel!



The same holds true when animating a tornado or whirl pool. A reflective area on the face of an undulating vortex simple has to jitter back and forth in place and the impression of spinning will be perceived because we know that tornadoes spin. Our preconceived ideas of how things move are often responsible for making this sort of animation work.

Another fantastic technique for creating surprisingly impressive effects, is the use of a **slot gag** and **actuator.** Initially this trick was used in conjunction with the back-lit techniques described earlier, but it is still useful today. The basic concept is that 2 or more designs on separate pieces of artwork, when moved against each other, create new and surprisingly beautiful designs when they interact. This technique can be used to create sparkling water surface f.x., or the sparkling effect on Jessica Rabbit's dress, or the beautiful radiating lights we see on the Paramount Pictures opening tag. Alot of experimentation is often necessary to achieve the desired results, but they are usually worth it, and to hand draw the same type of f.x. would be next to impossible.

The Animator As Actor

by Steven Paul Leiva

The Animator as Actor — it's a simple concept, a statement complete enough to require no explanations beyond its own words. But somewhere this simple concept has been lost, or forgotten, or possibly never even considered by the public, and, more importantly, by the press which gives the public much of the informatio upon which it forms impressions. When the general press runs an article on animation, it is almost inevitable that the main point made, the "news" imparted, will be that there were, "Over so many odd thousands of drawings made to complete this film." Then everybody goes "Oooh!" and "Ahh!" and shake their heads in wonder as if they were being told how many hairs there are on a centipede's leg. The impression is made that an animator is only and just an individual who does a tremendous -- possibly a tremendously silly -- amount of drawings that are somehow strung together to make a "cartoon.". Animators are seen almost as manual laborers -- ditchdiggers with pencils -- with brows covered with sticky sweat instead of (as it actually is) the furls of creative concentration. This, of course, is all wrong. For as Chuck Jones has said, "Animators do not draw drawings, they define characters."

Drawings for animators are simply the instrument through which they act, emote, mime, dance, and create characters as real as any devised by nature. Their successive drawings are their instrument in no less a way than a "live" actor's body, a singer's voice, or a pianist's piano are their instruments. But no one ever seems concerned over how many individual moves an actor makes to complete a scene, how many notes a singer hits to complete a song, or how many keys Horowitz strikes during his playing of Rachmaninoff's second piano concerto. The concern is over how well they acted, sang, or played; how they -- as artists -- interpreted the scene, song, or composition. It should be the same for animators. For it is not really the drawings that matter, or how many there are, but, rather, what matters is how well the animator succeeds through successive drawings in breathing life into the characters his lines define. The animator plays drawings, utilizing "movement scales" rather than musical scales to realize a desired effect. The animator mimes action, but he does it on paper, instead of with his body.

Exactly how the animator does this cannot really be explained. But neither can it be explained exactly how Horowitz so brilliantly interprets Rachmaninoff. You can't just say, "Well, he hit all the right keys at the right times." It is something more wonderfully mysterious than that, something more interior. And so is animation. You cannot just report the thousands of drawings it takes, and feel that you've explained it. You have to try for a deeper understanding.

As you view the classic character animation in this program, realize that what you are seeing are not drawings that move and act, but rather, movement and acting that is drawn.

Motivated for Effects

Notes from Dorse on MOTIVATION 3/31/97

People who are *not interested* are people who are *not interesting.* You have probably found, from your own experience, that people who are **interested in you** are people who are more **interesting to you.** The key is the *interest!* The interest motivates.

***Interest...**A feeling of curiosity or concern about something.*

***Interesting...**Arousing or holding attention.*

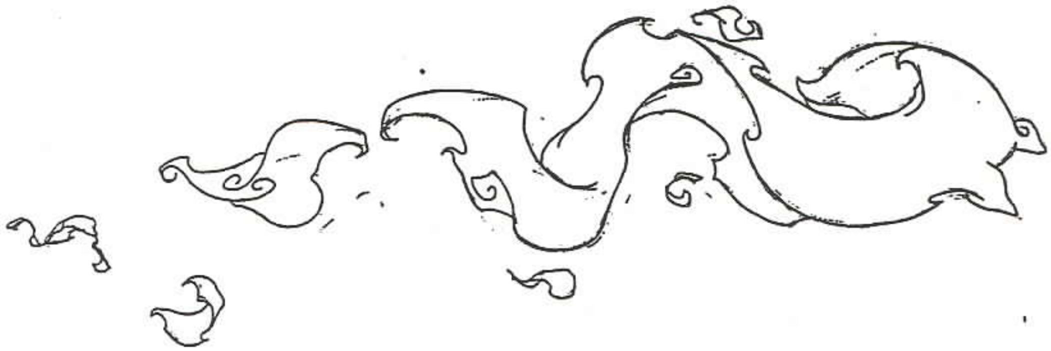
***Motive...**An emotion acting as an incitement to action.*

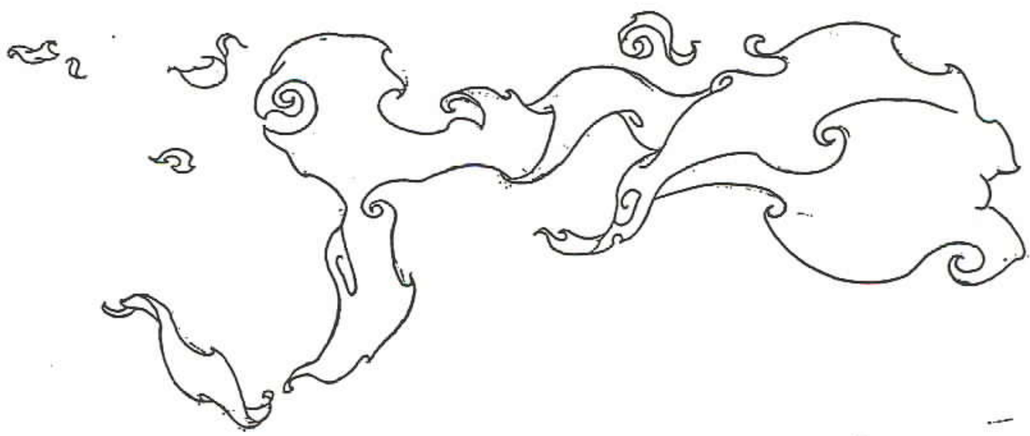
To be an effects animator... *to be anything*...one must be motivated, interested. The broader the interest is to the motivation the more effective you will be at whatever it is you want to be. A lousy bank robber will be someone who is only interested in the money. Chances are it won't be long before that robber is caught. An effective bank robber will be someone whose interests cover all aspects of the job. An interest in bank security systems, the layout of the building, number of personnel, etc. will be only some of the areas of interest. The more attention paid to these details the more effective the robber will be. The money will follow. Hopefully a long prison sentence will also follow because it's not nice to steal other peoples' hard-earned money.

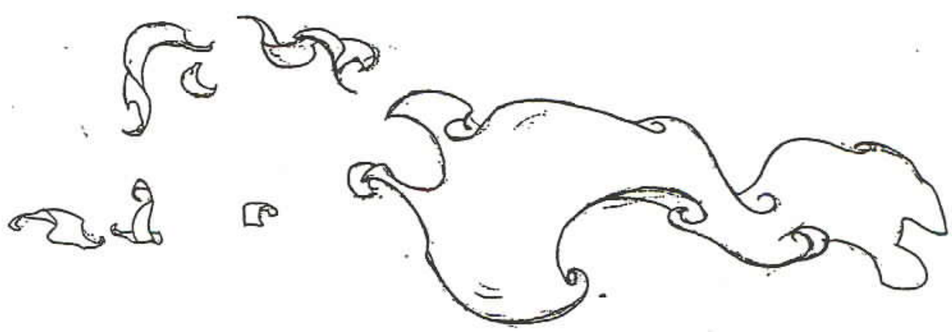
Now... if you want to animate effects you need to have an interest in *things. Everything.* You will be called upon to make an audience believe that they are experiencing a fantasy on the screen of which an important ingredient will be any number of different effects. The more things you're interested in and know about, the better animator you will be and the more fun you will have doing it. No one will put you in jail for it and the money will follow. We all have to make a living!

ART... Many people have said "I don't know what art is but I know what I like." I think art is something someone has constructed which the majority of the people of a given system are attracted to. How presumptuous of me!

If a person attempts to animate effects by copying other peoples' work and

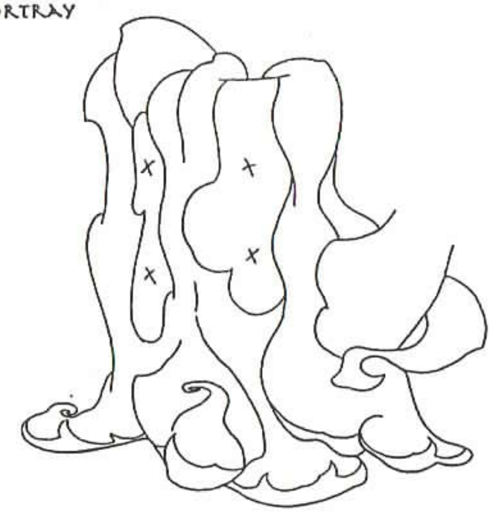






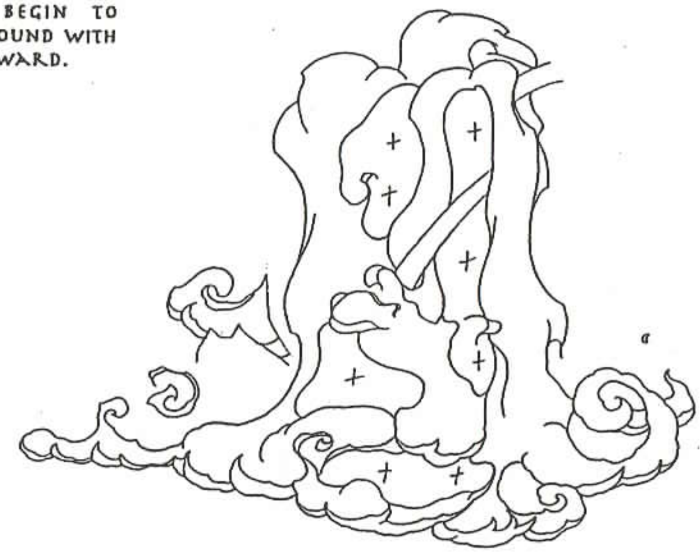
UNDERWORLD DRY ICE SMOKE

* DRAW SMOKE ON 2'S USING TRAITS OF DRY ICE, BUT NOT AS LIGHT. IT SHOULD STILL PORTRAY SMOKE.



1

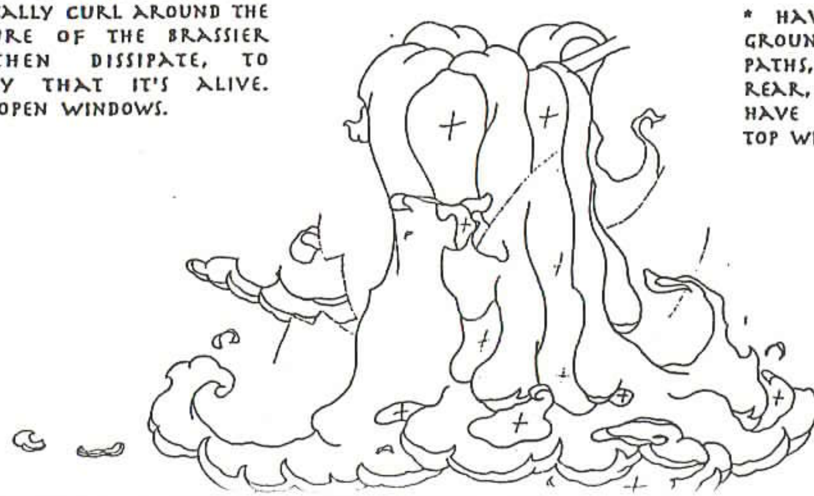
* THE SMOKE WILL BE PROTRUDING DOWNWARD FROM BRASSIER IN A HEAVY MOVEMENT. AS IT HITS THE GROUND, IT WILL BEGIN TO CRAWL ALONG THE GROUND WITH PORTIONS CURLING UPWARD.



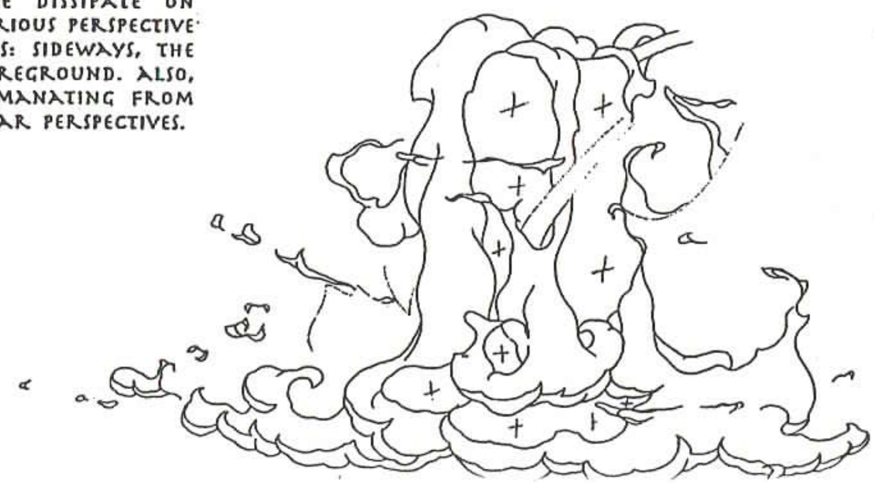
2

* CLEAN UP SMOKE USING SMOOTH AND RAZOR TYPE SHAPES. KEEP SINISTER FEEL TO IT. FOLLOW THROUGH WITH RAZOR CLEAN UP LINES.

* FINGERS OF THE SMOKE WILL PERIODICALLY CURL AROUND THE STRUCTURE OF THE BRASSIER AND THEN DISSIPATE, TO PORTRAY THAT IT'S ALIVE. CREATE OPEN WINDOWS.



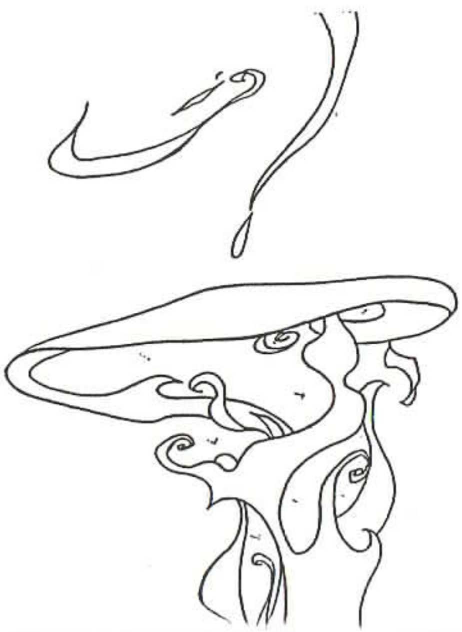
* HAVE SMOKE DISSIPATE ON GROUND IN VARIOUS PERSPECTIVE PATHS, SUCH AS: SIDEWAYS, THE REAR, AND FOREGROUND. ALSO, HAVE SMOKE EMANATING FROM TOP WITH SIMILAR PERSPECTIVES.



UNDERWORLD BACKGROUND SMOKE

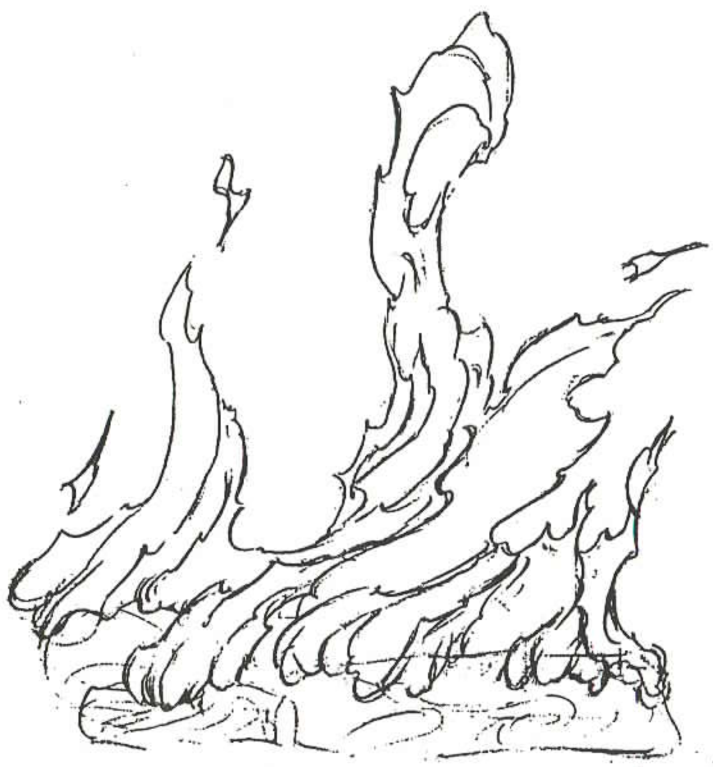
* SMOKE SHOULD ALWAYS EXPAND FASTER IN THE HORIZONTAL PLANE THAN IN THE VERTICAL. IT SHOULD GIVE THE AUDIENCE AN IMPRESSION OF THE ENVIRONMENT BEING VERY HEAVY/GLOOMY.

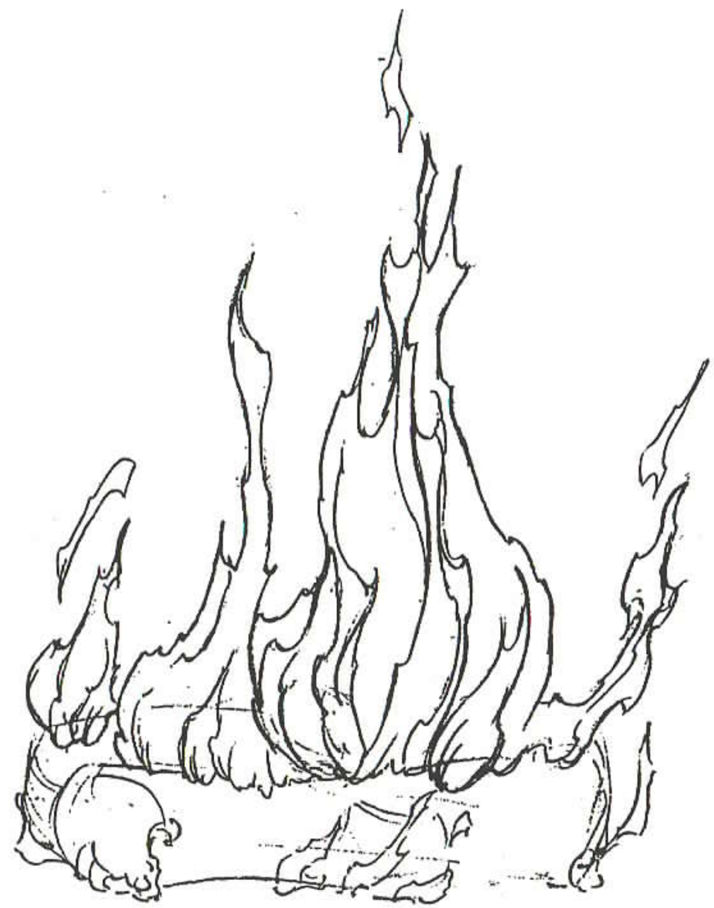
* SHAPES WITH SHARP POINTS THAT TRANSITION TO SLOW CURVING SHAPES.



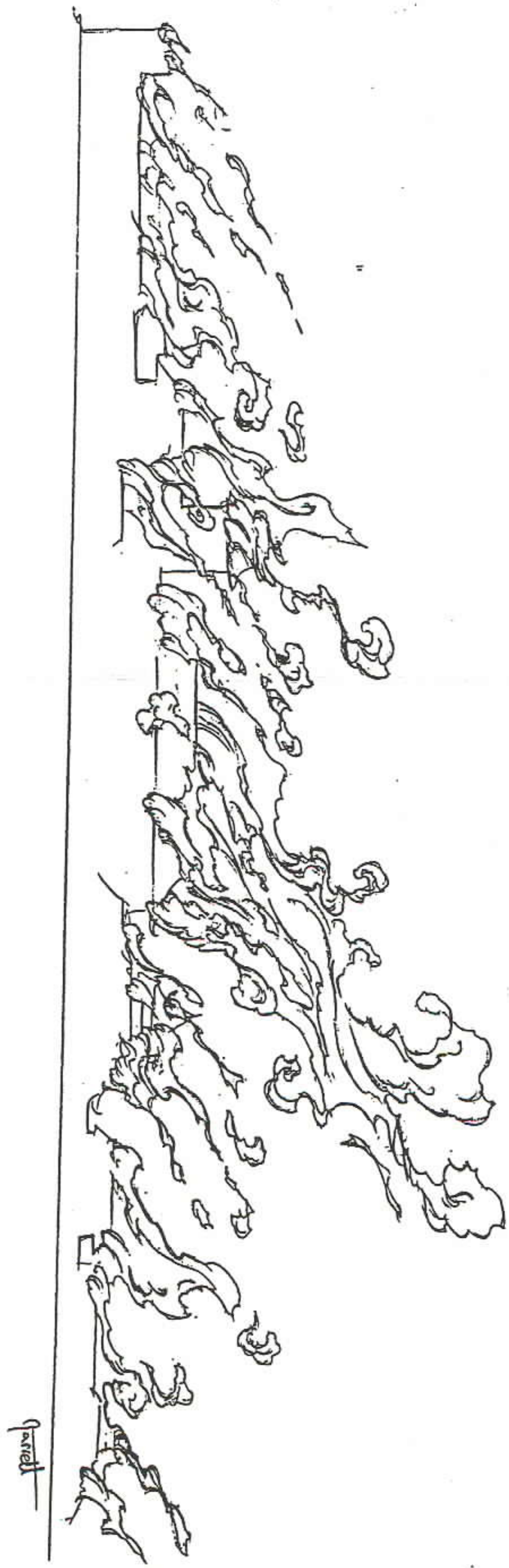
* OPPOSING CURVE PATTERNS

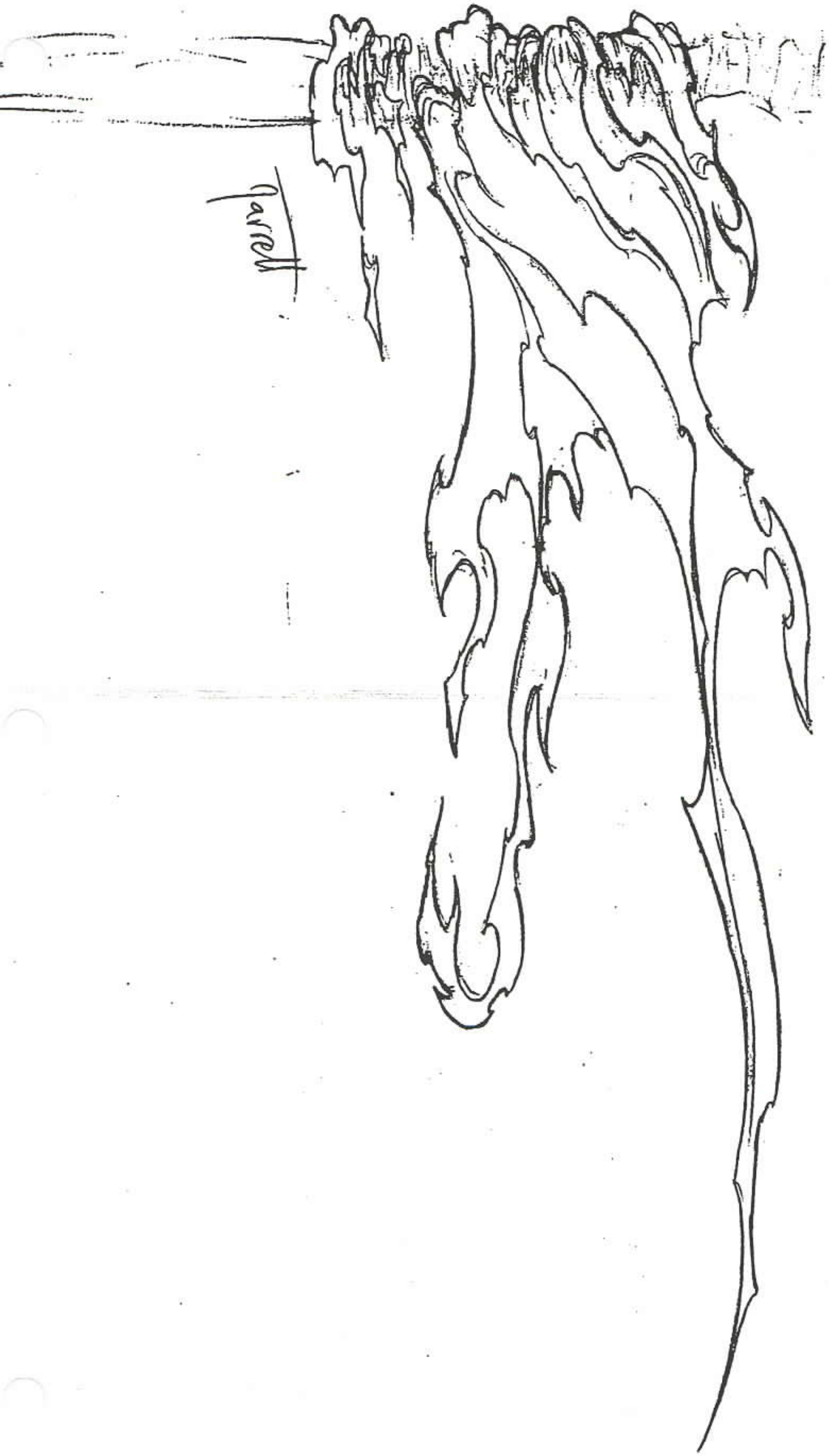
* STRONG SWEEPING LINES

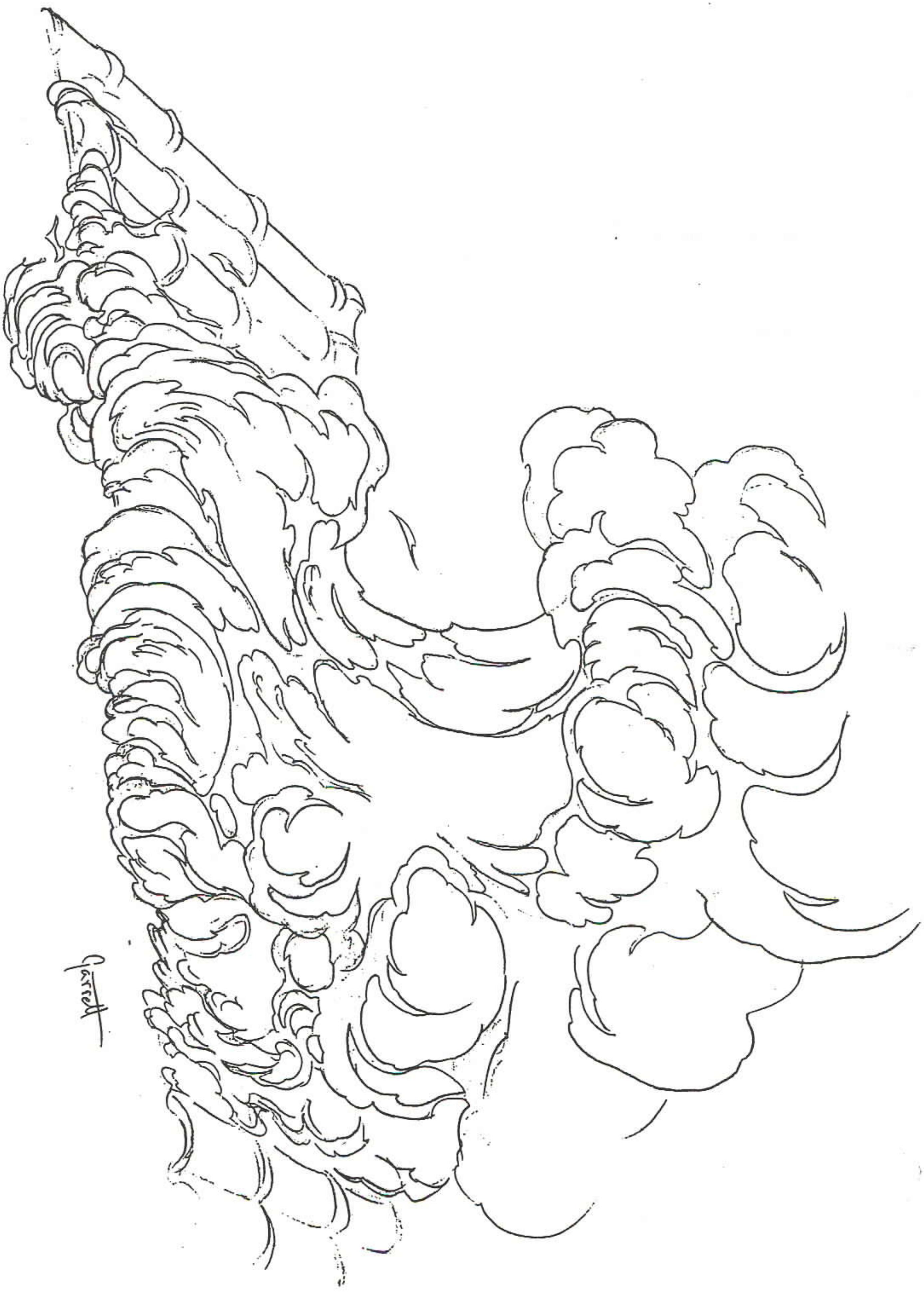




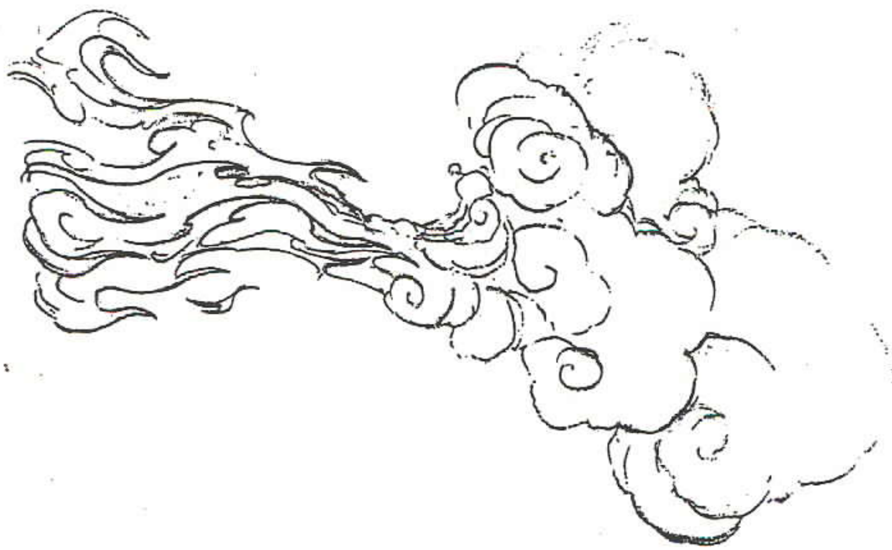
Garrett

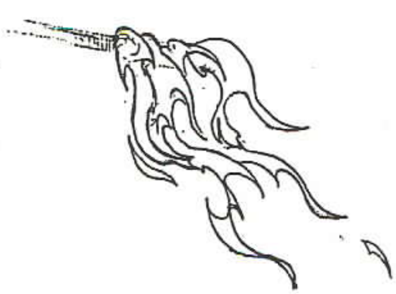


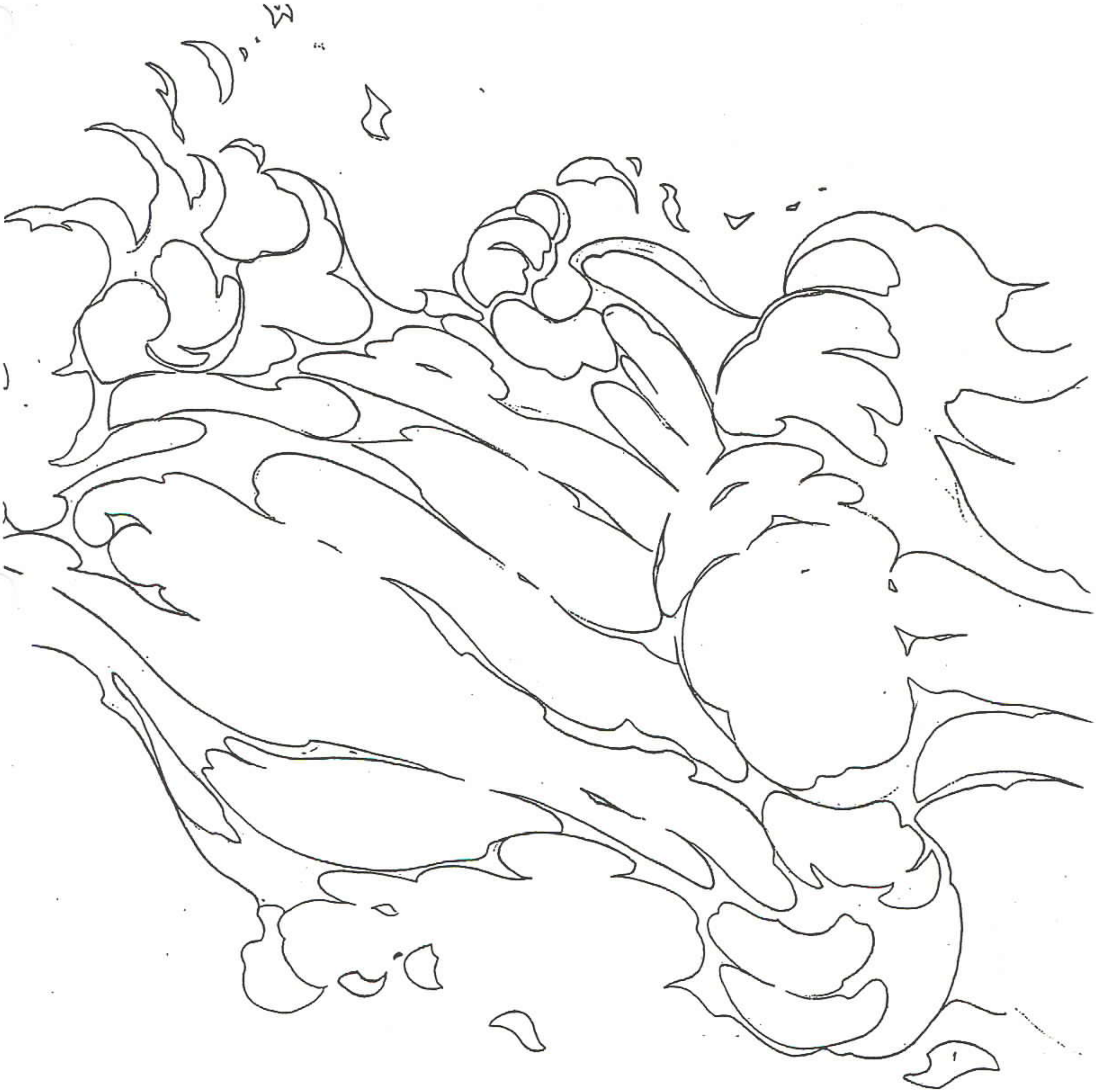

Jarrett

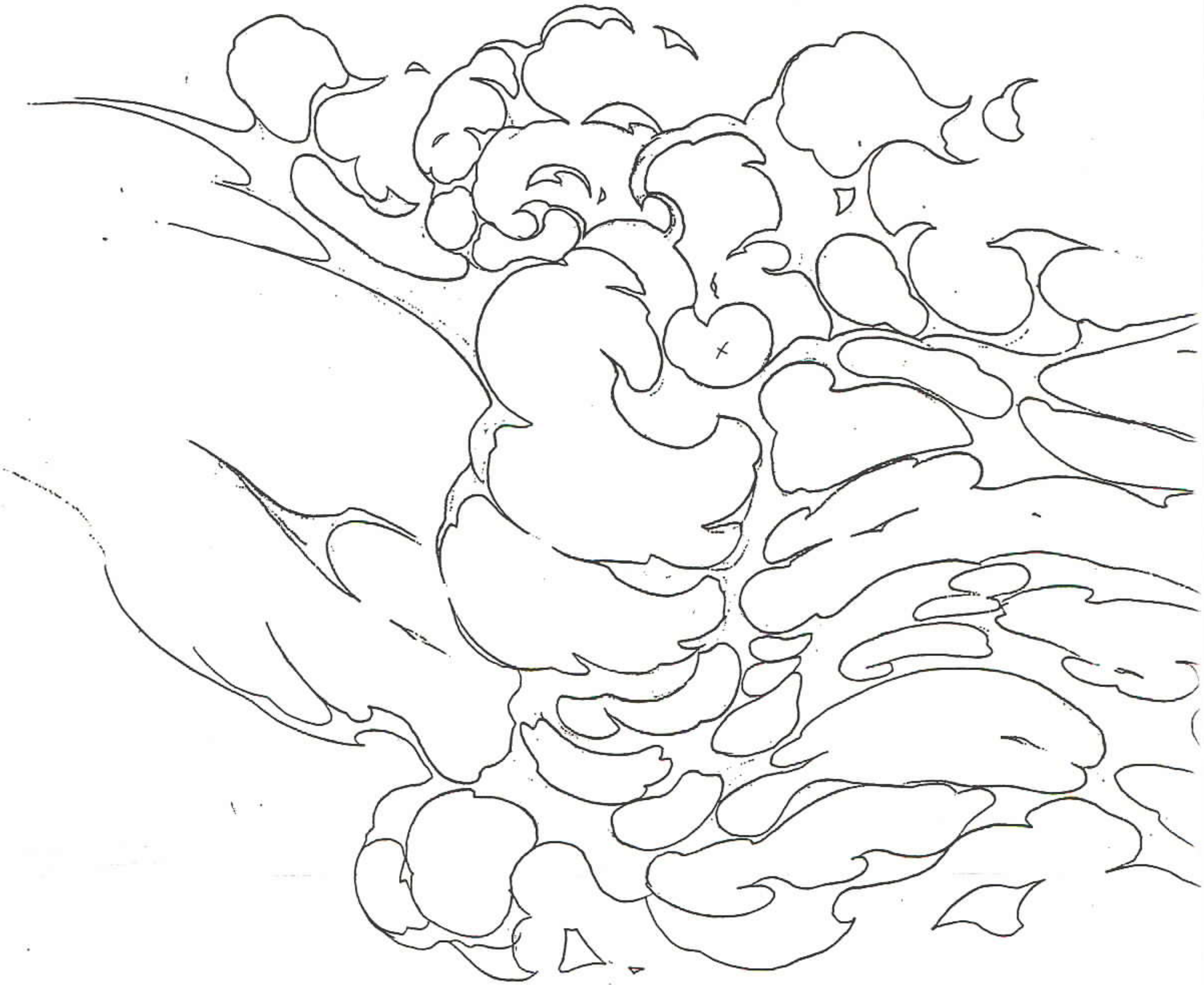

Garrett

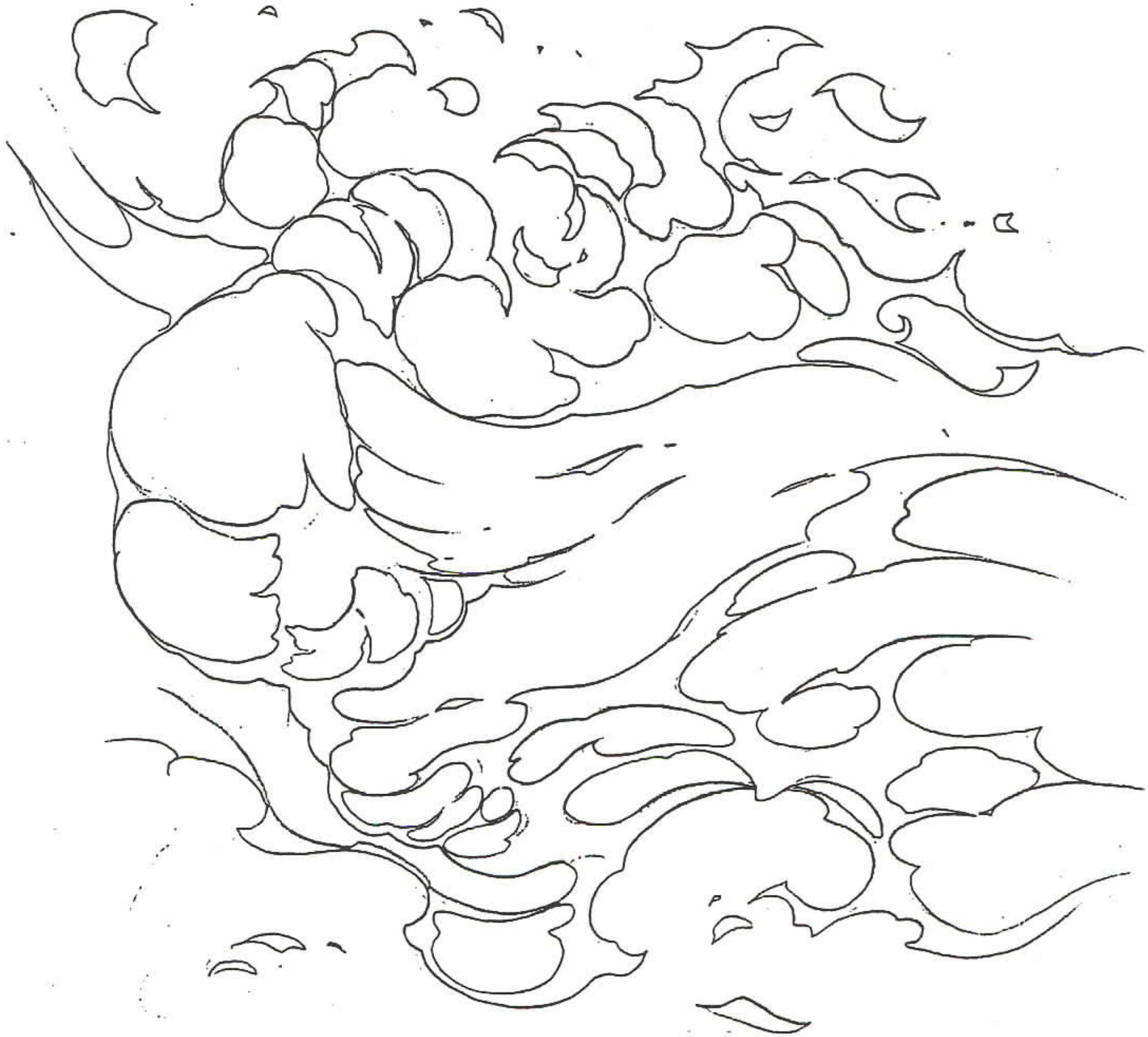

Garrett

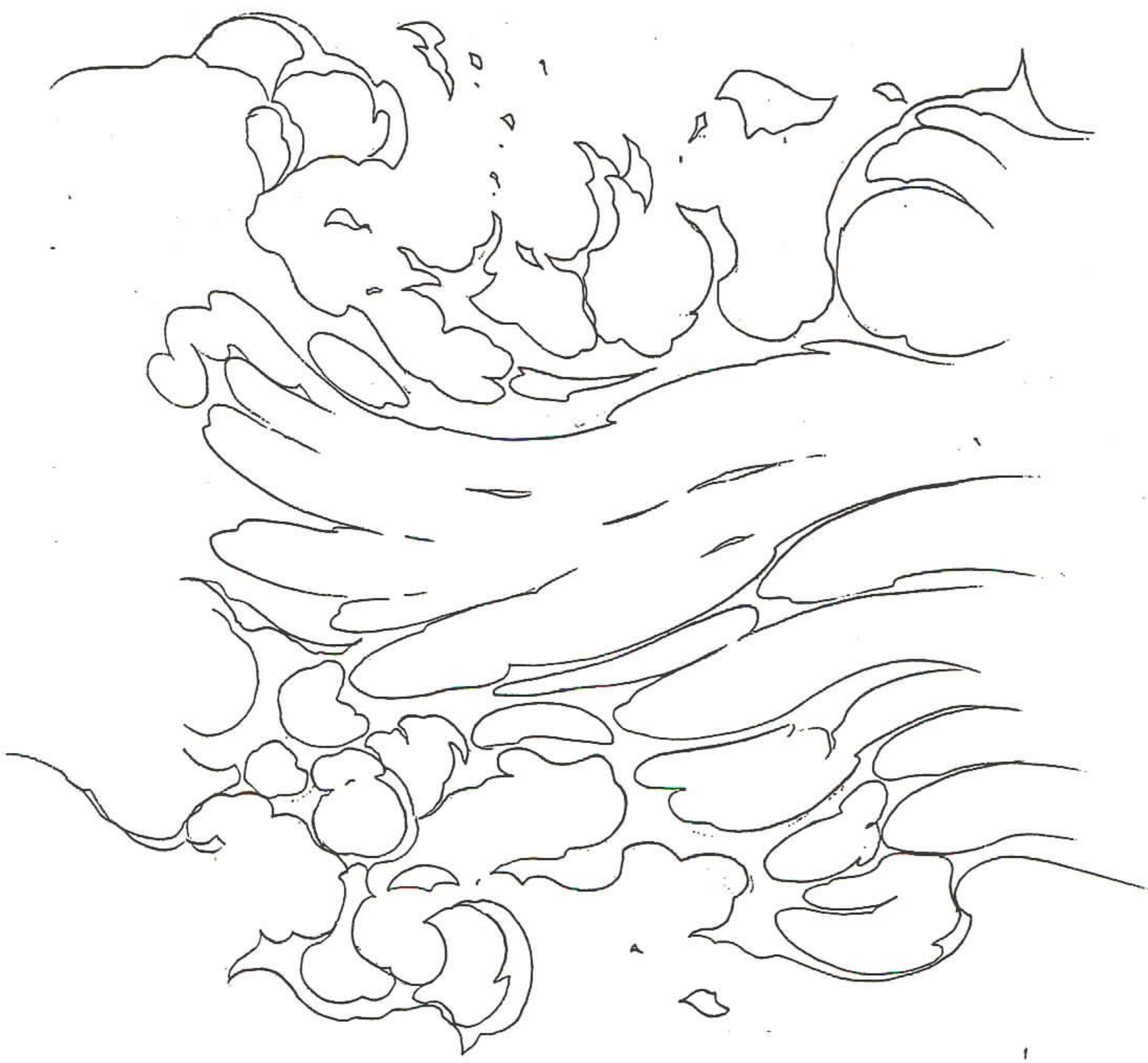


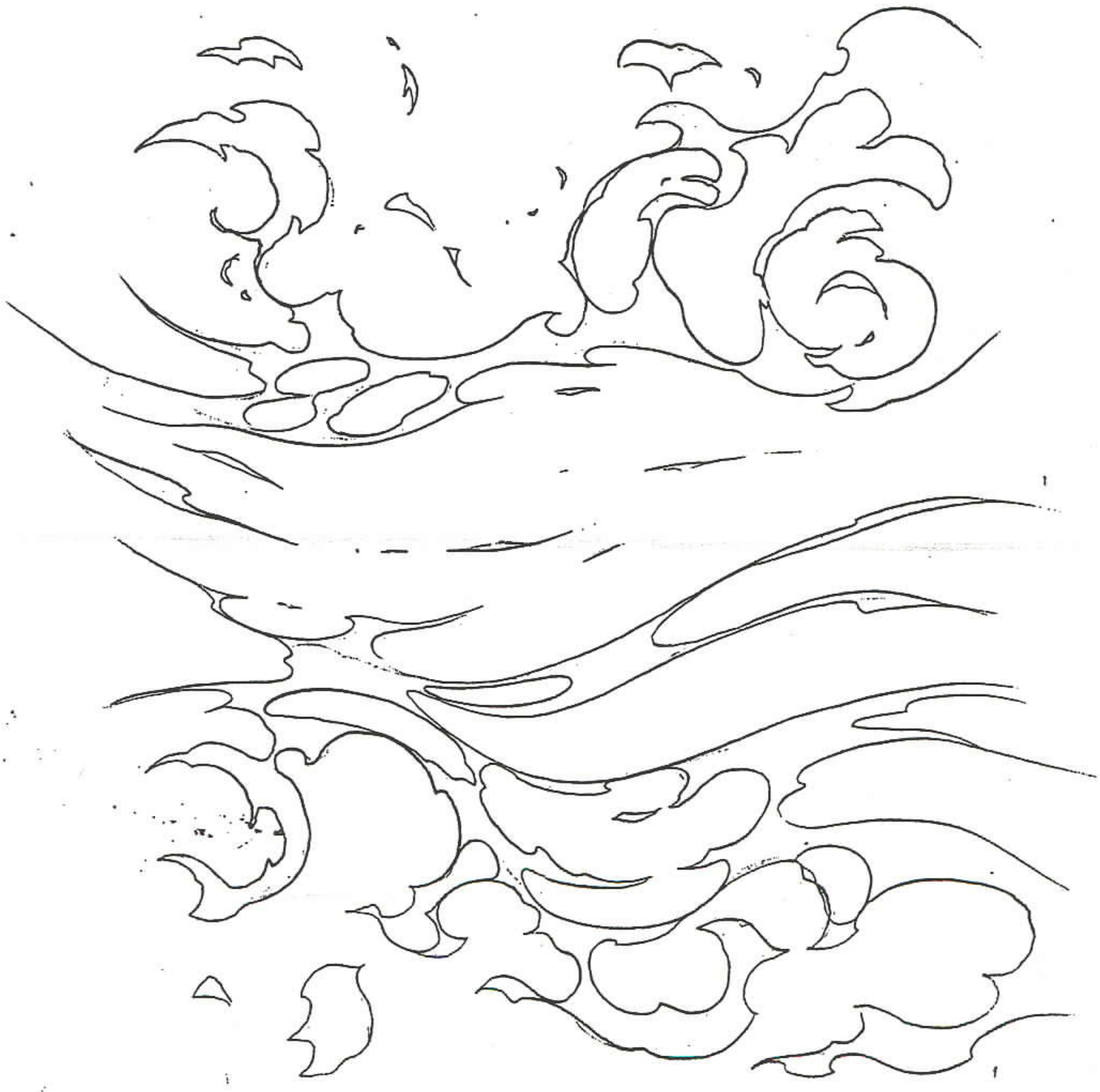


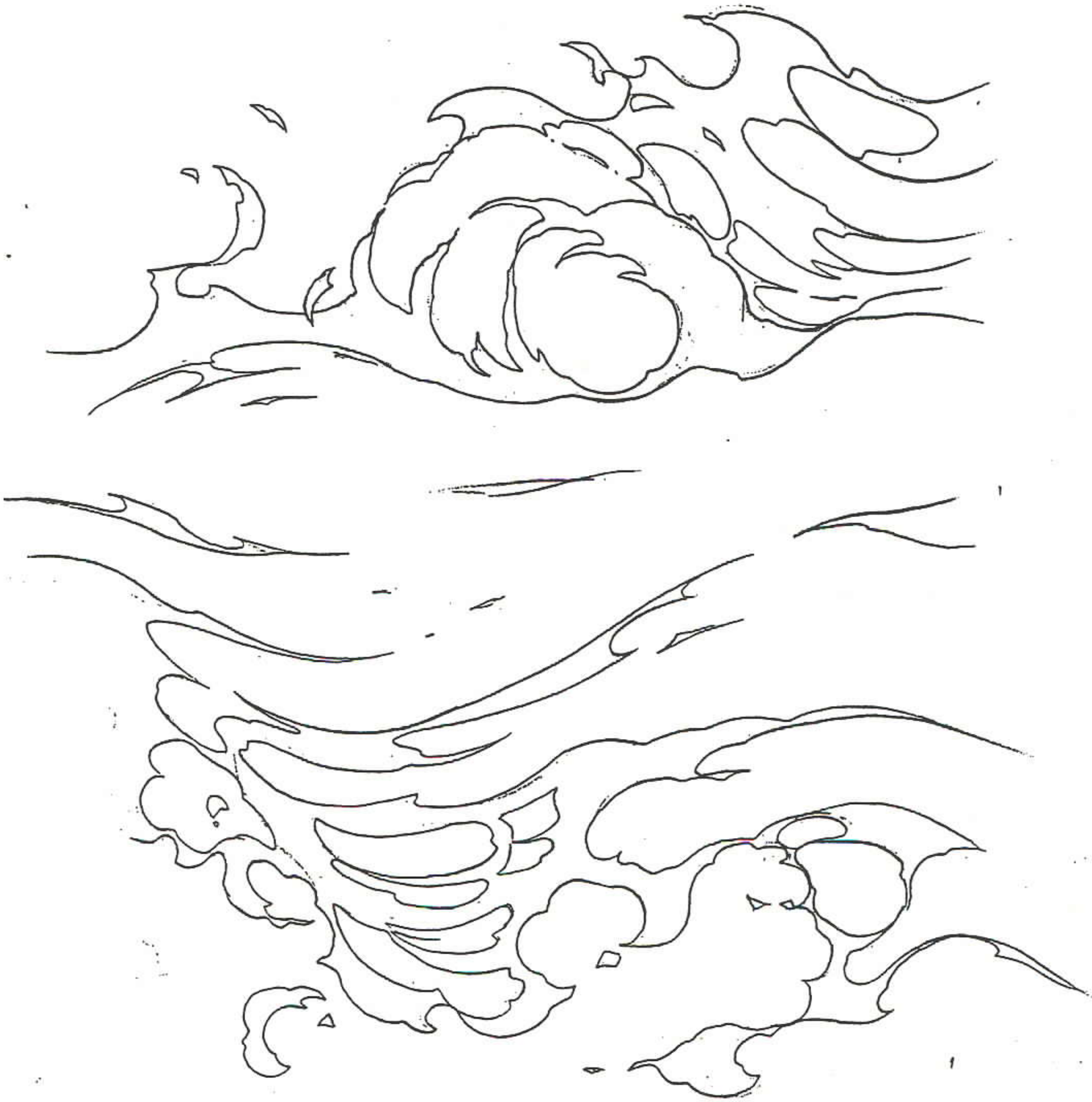


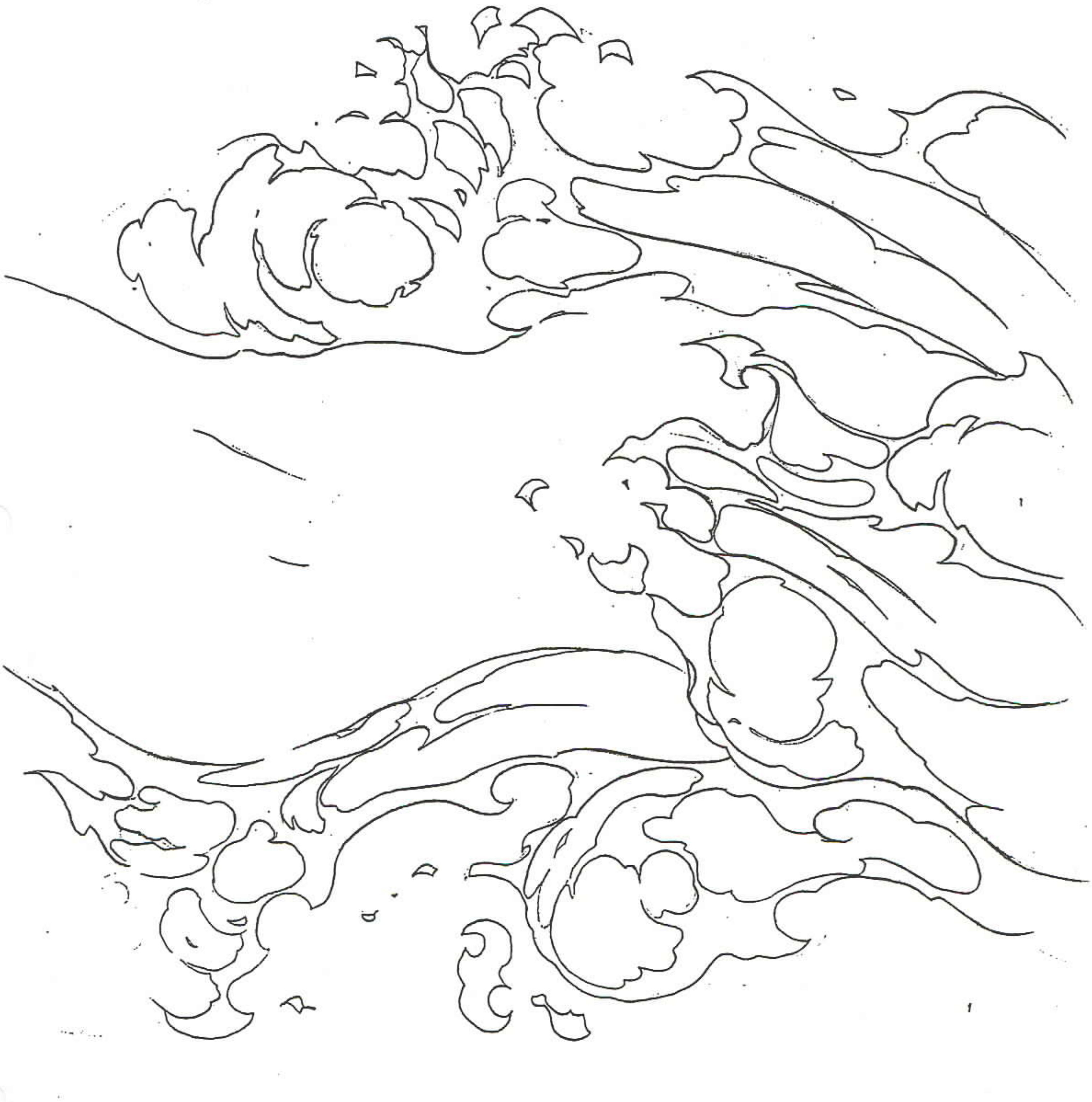


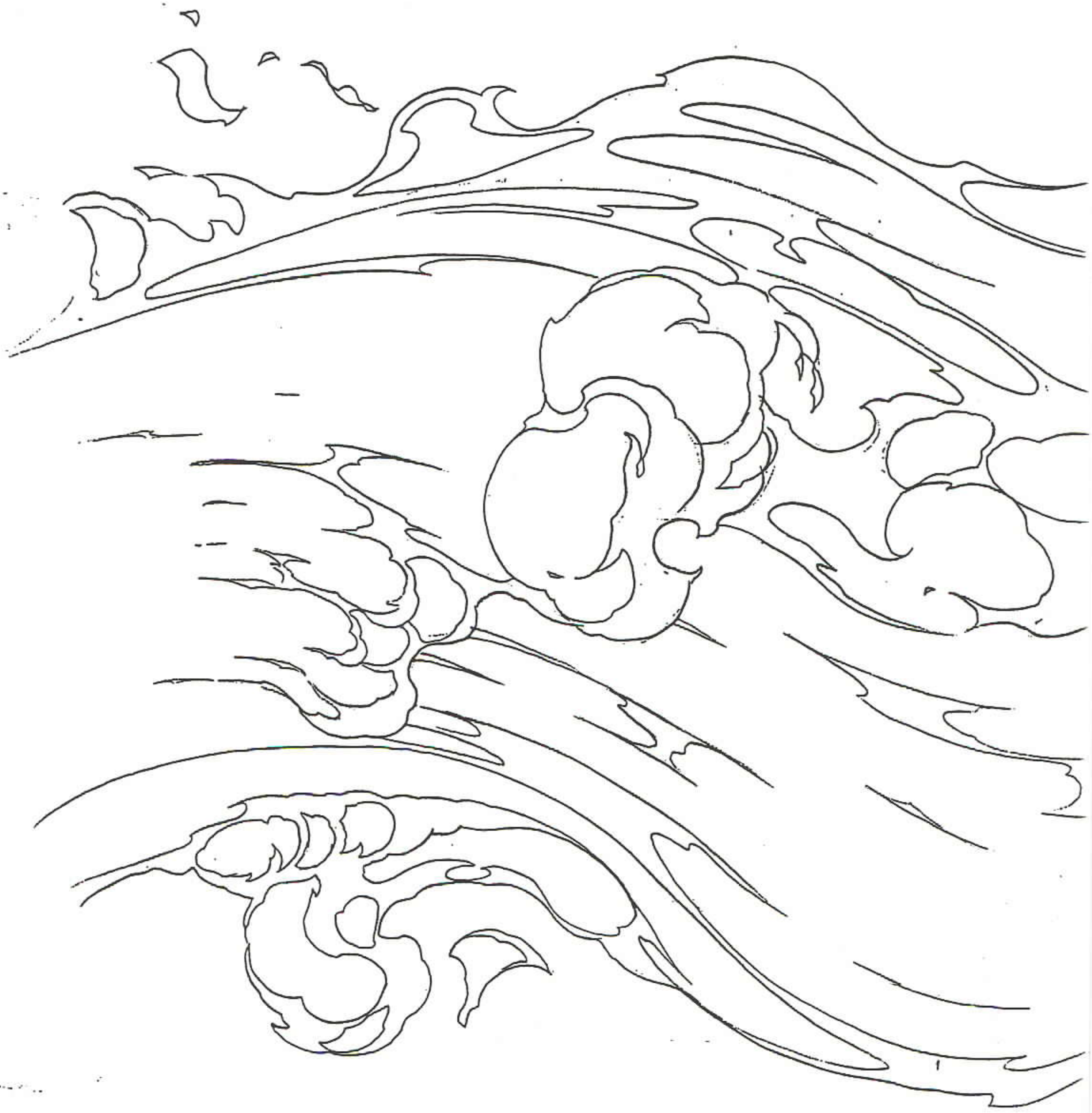


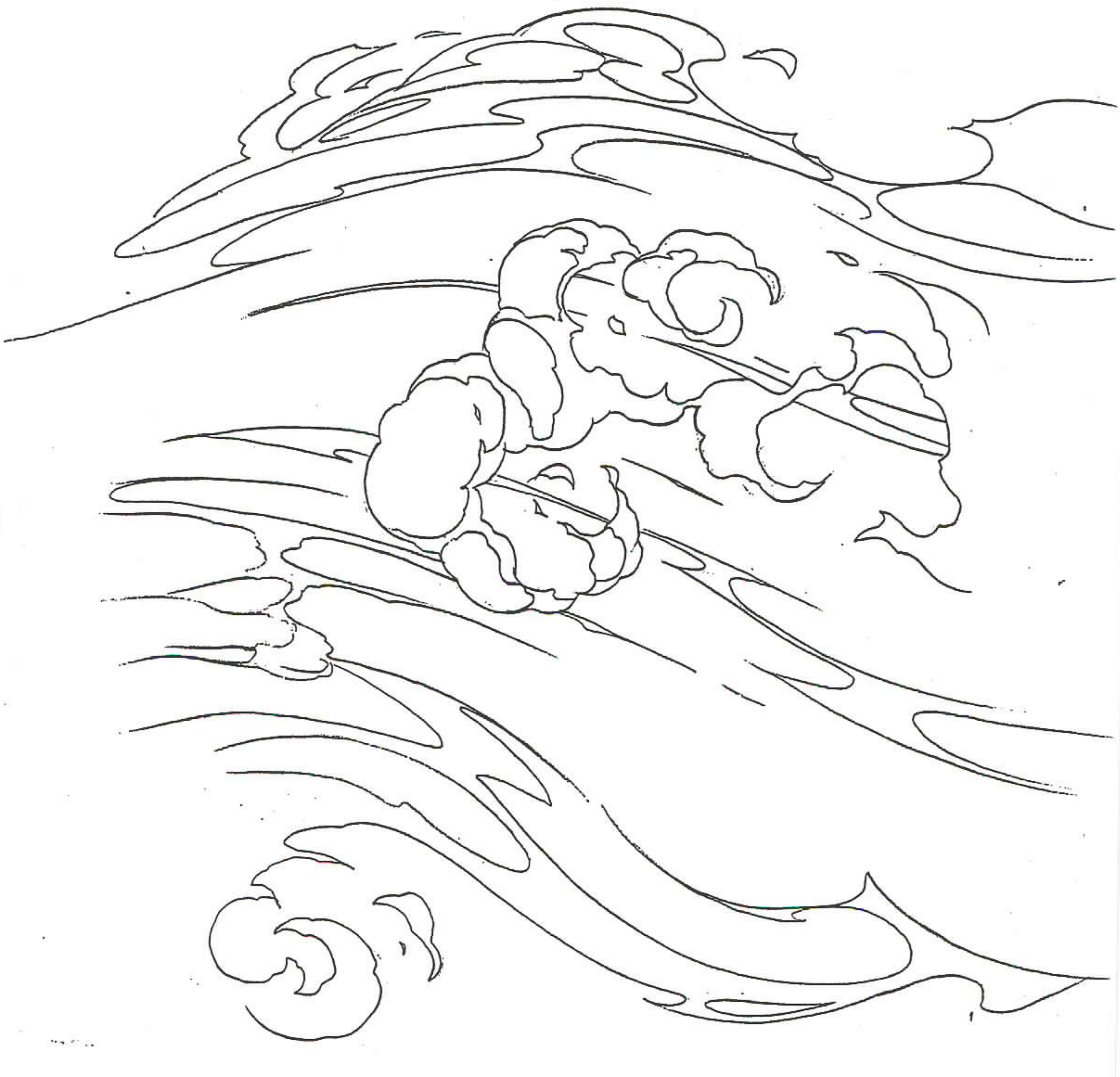


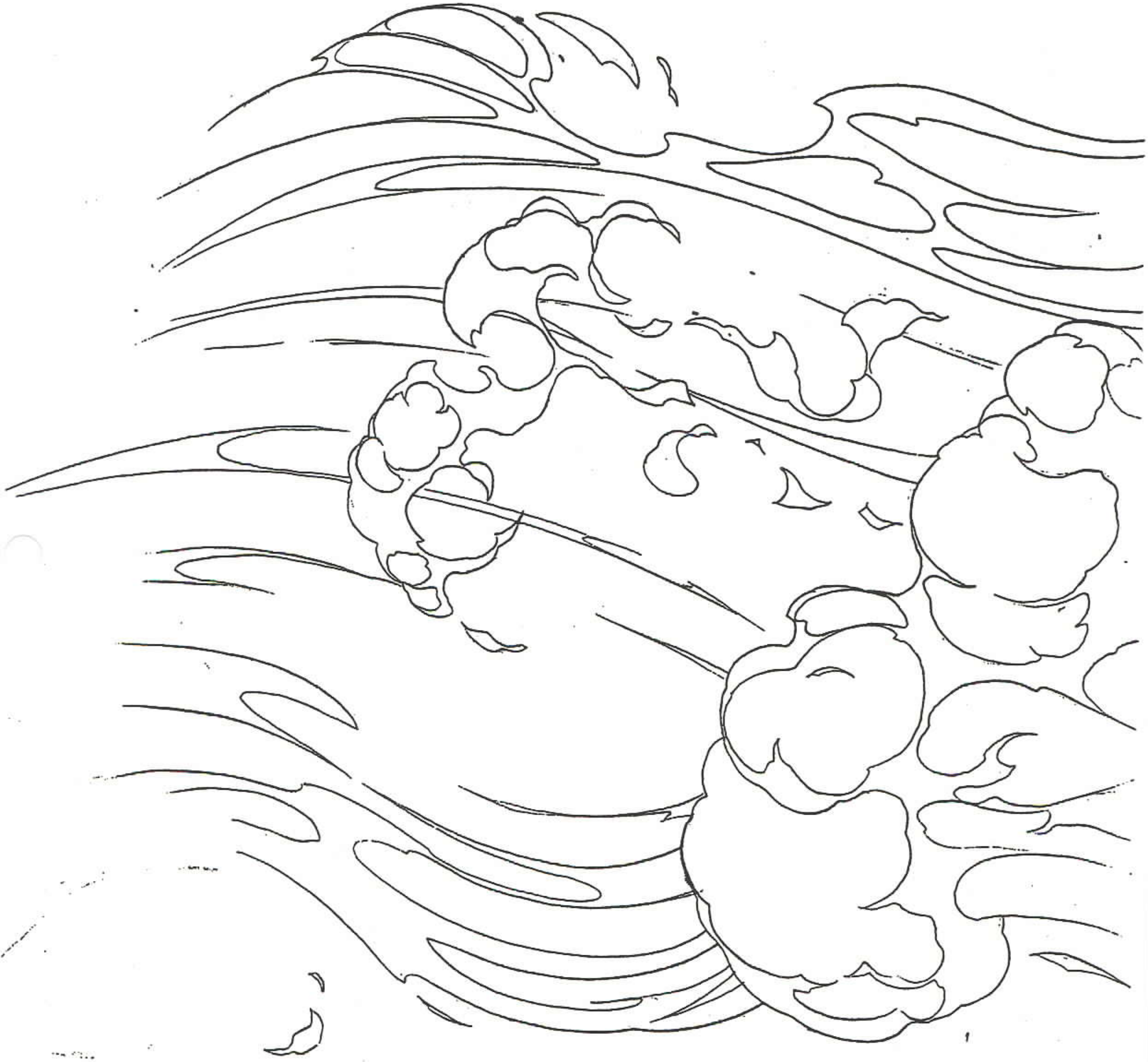


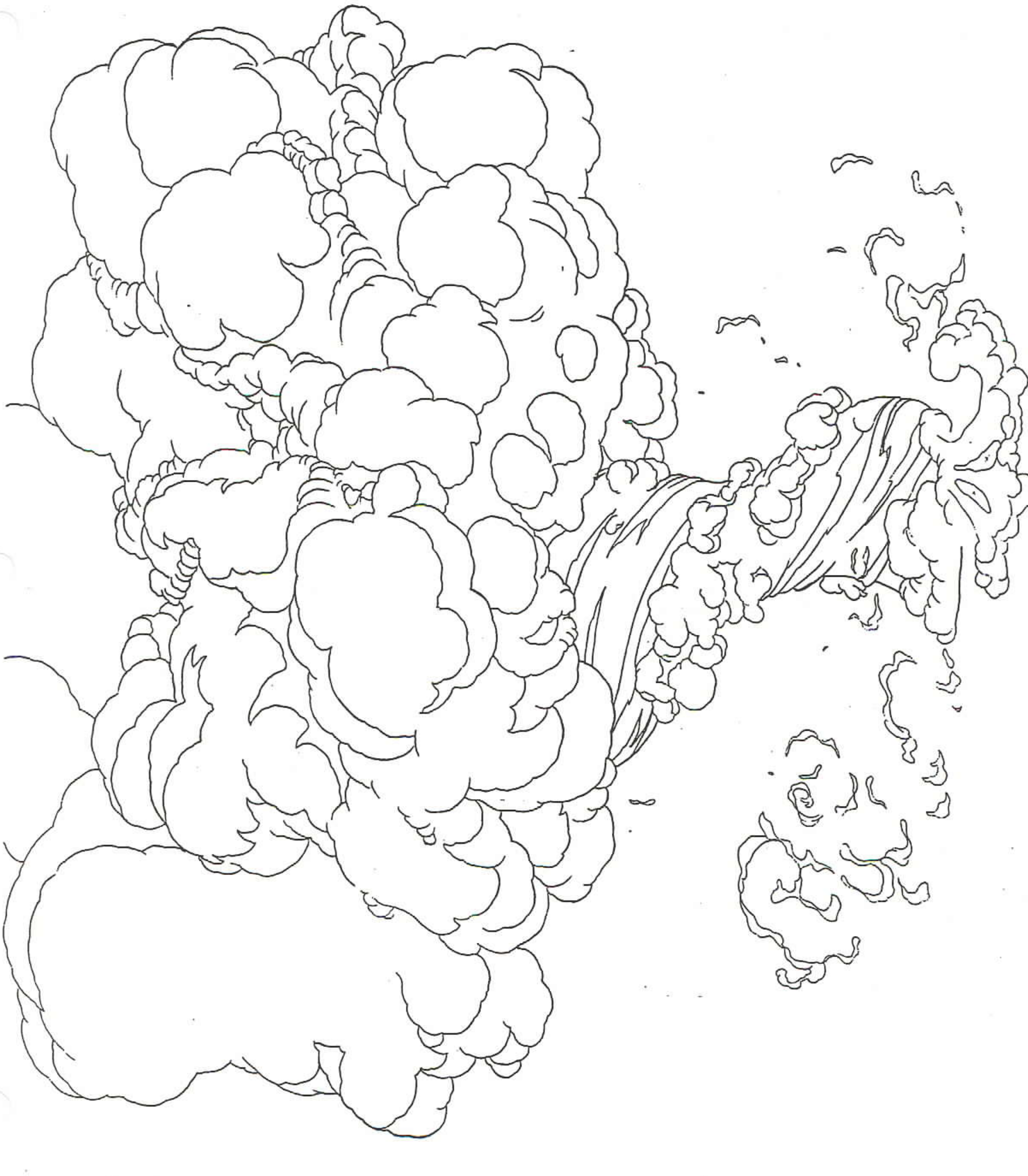


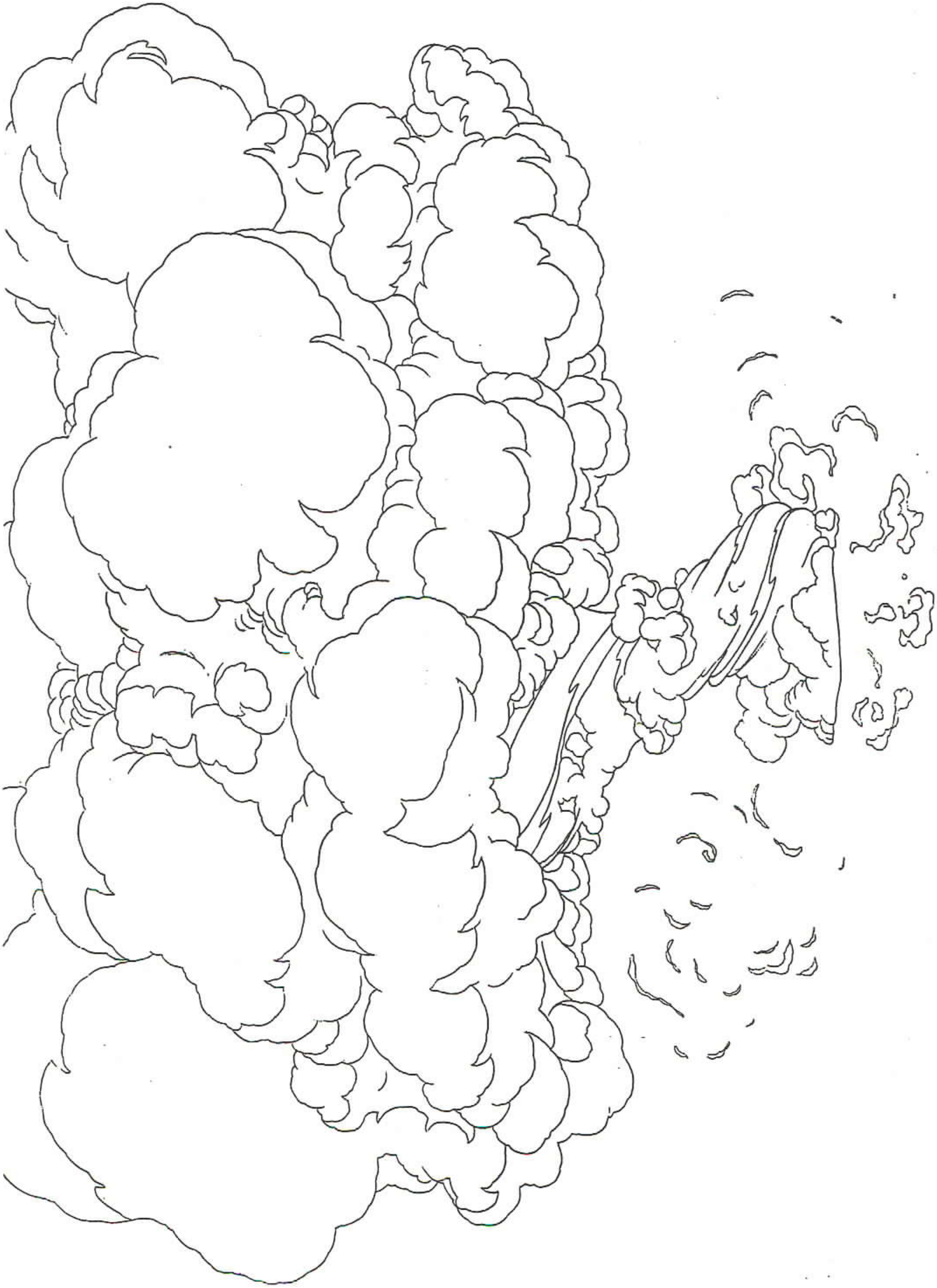


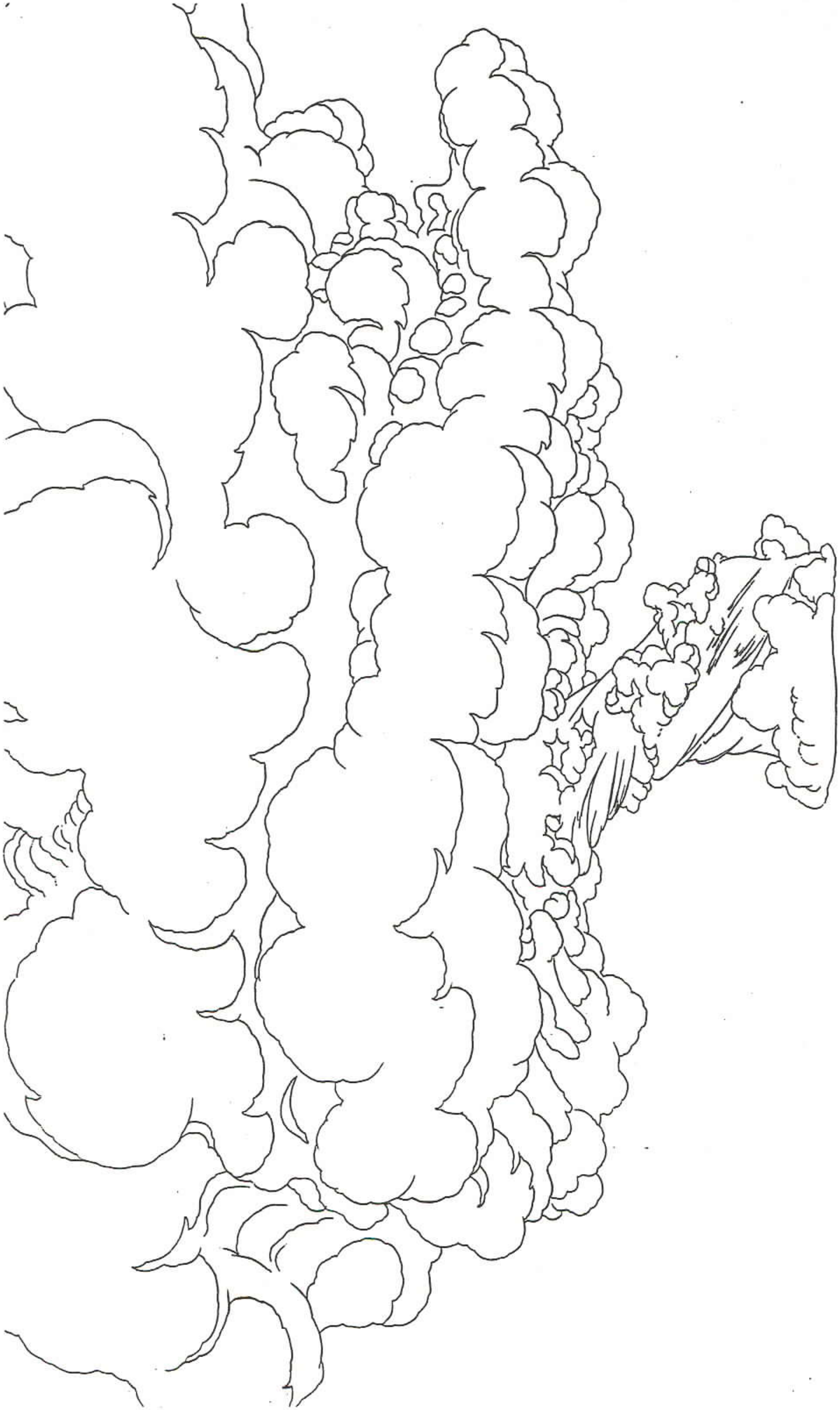


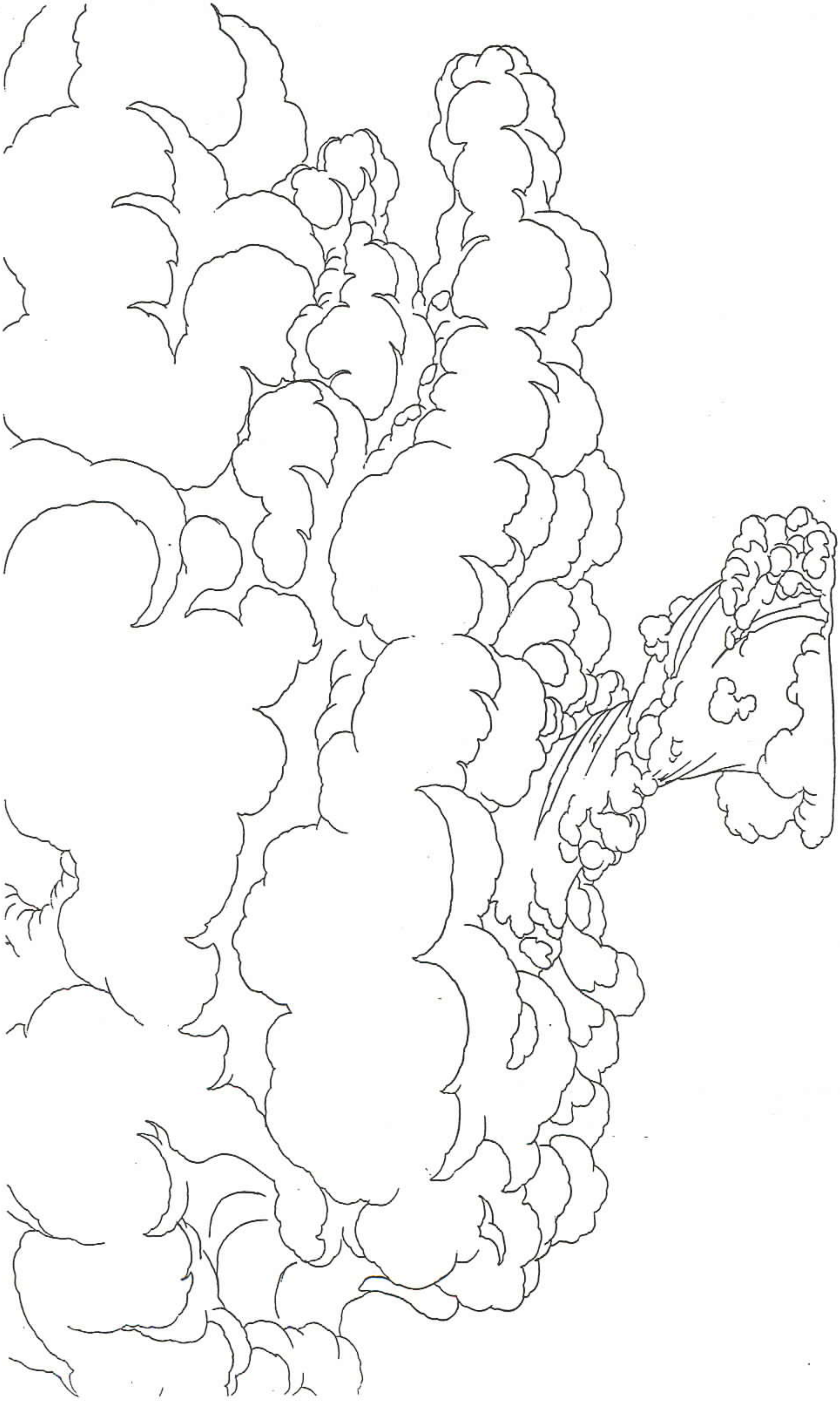






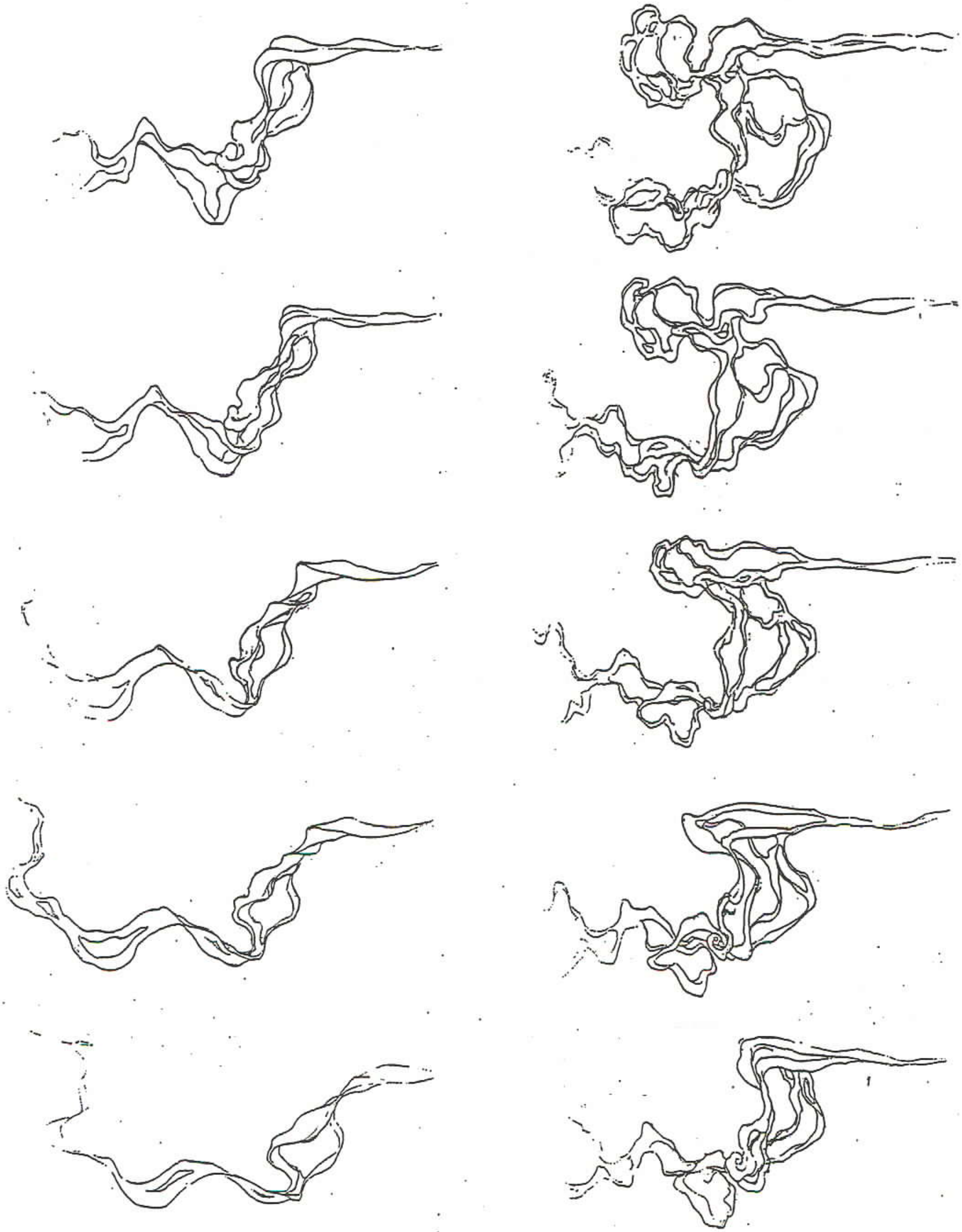


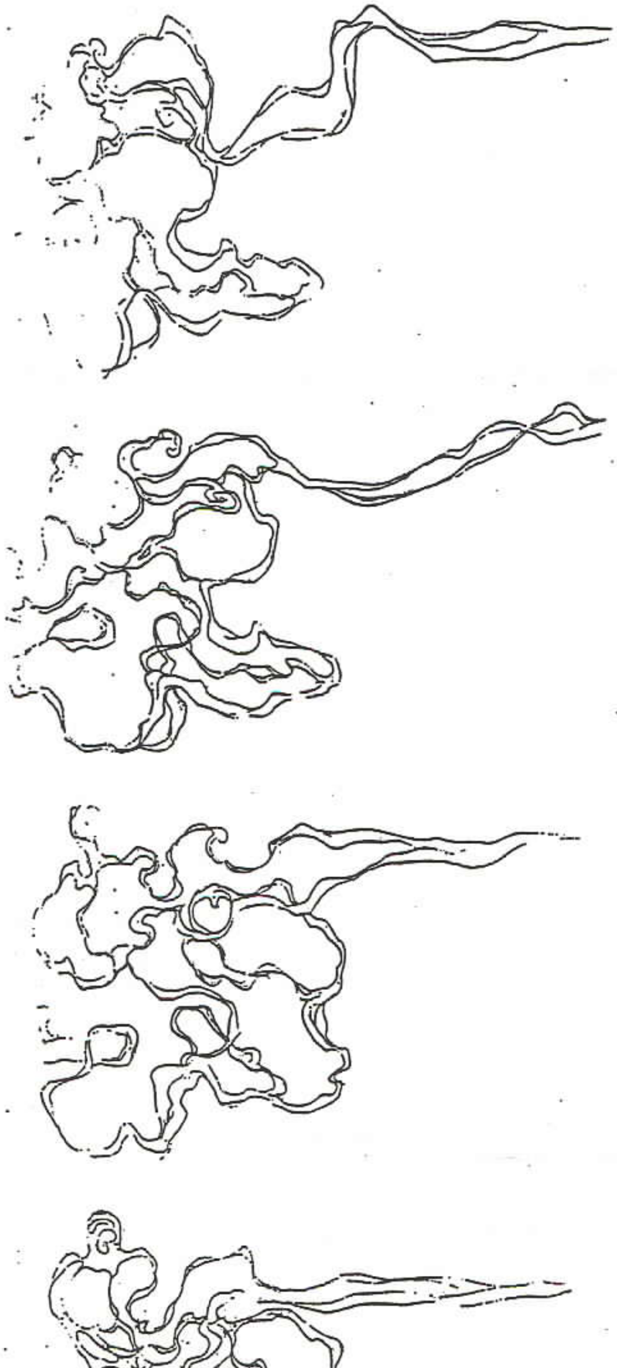




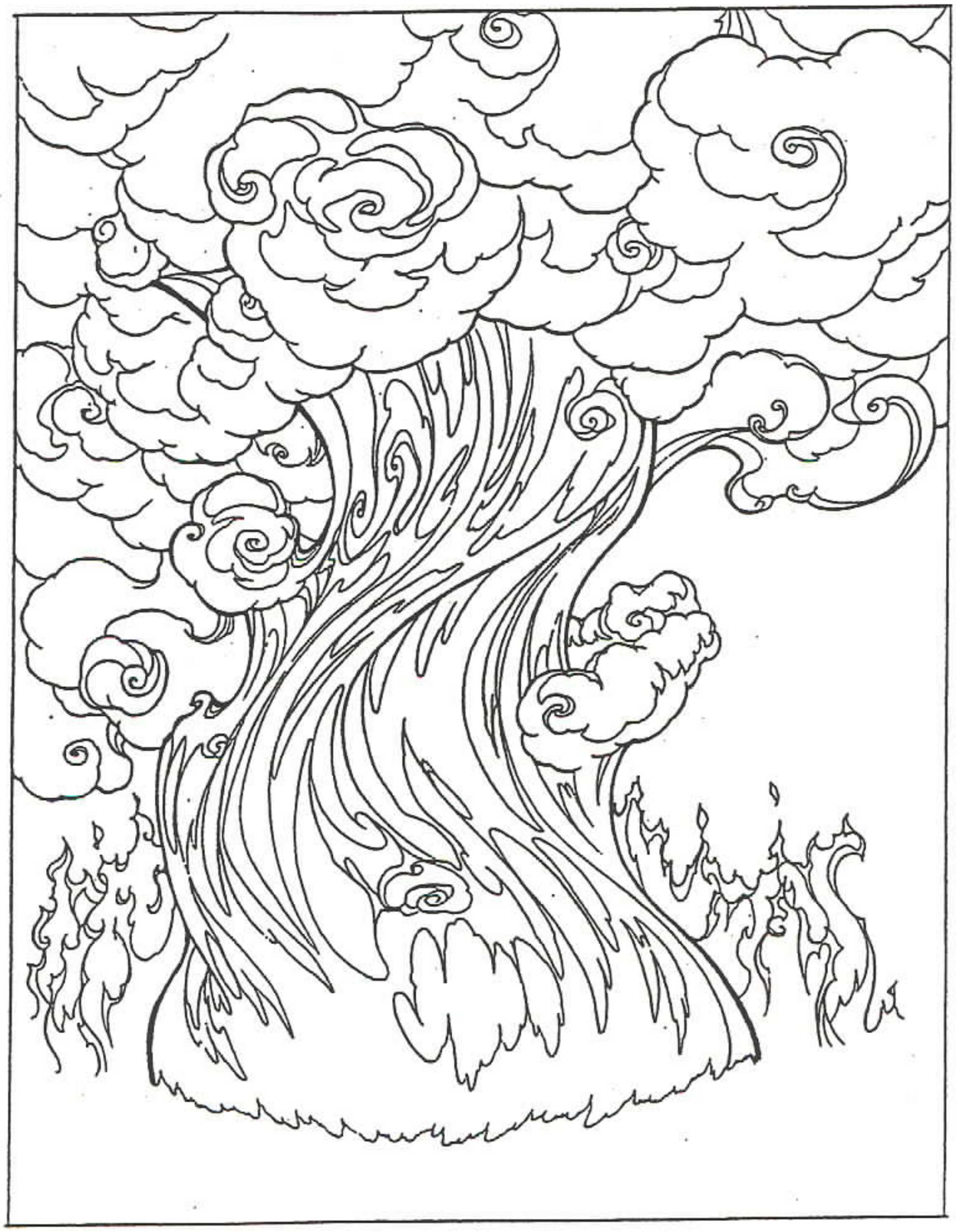
oil lamp

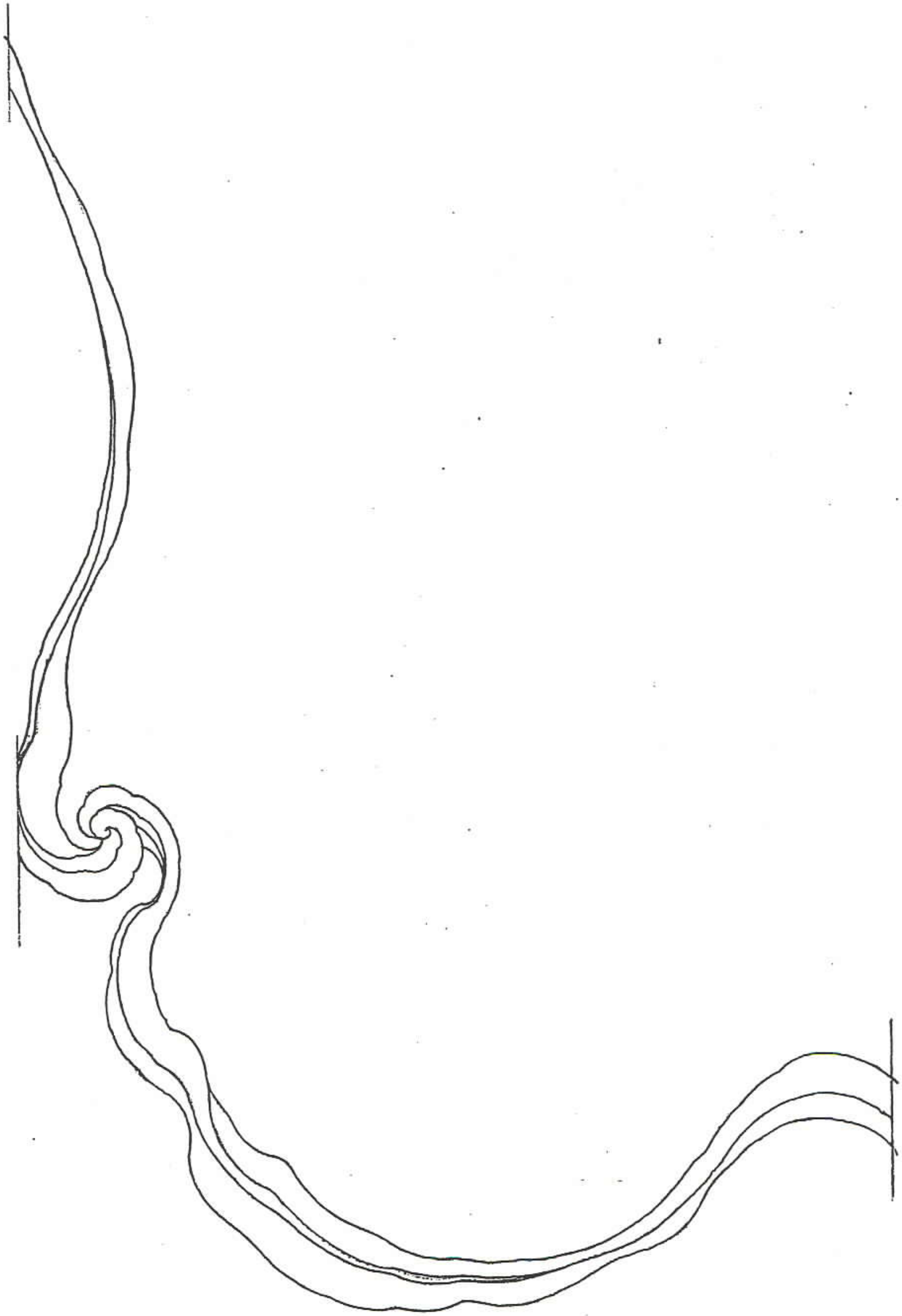
oil lamp.

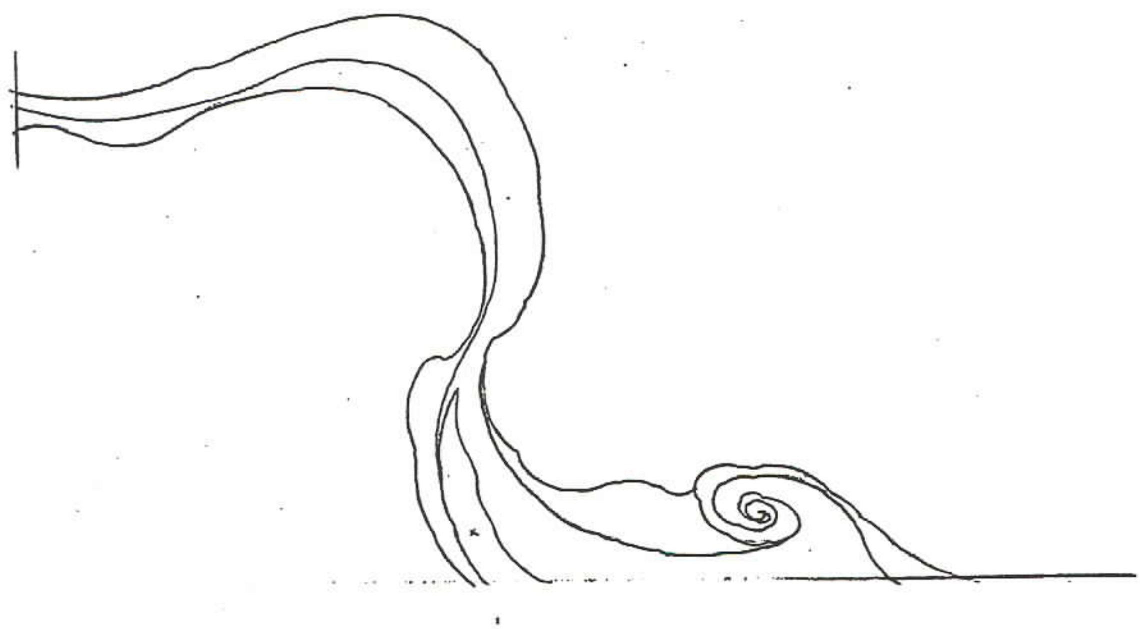


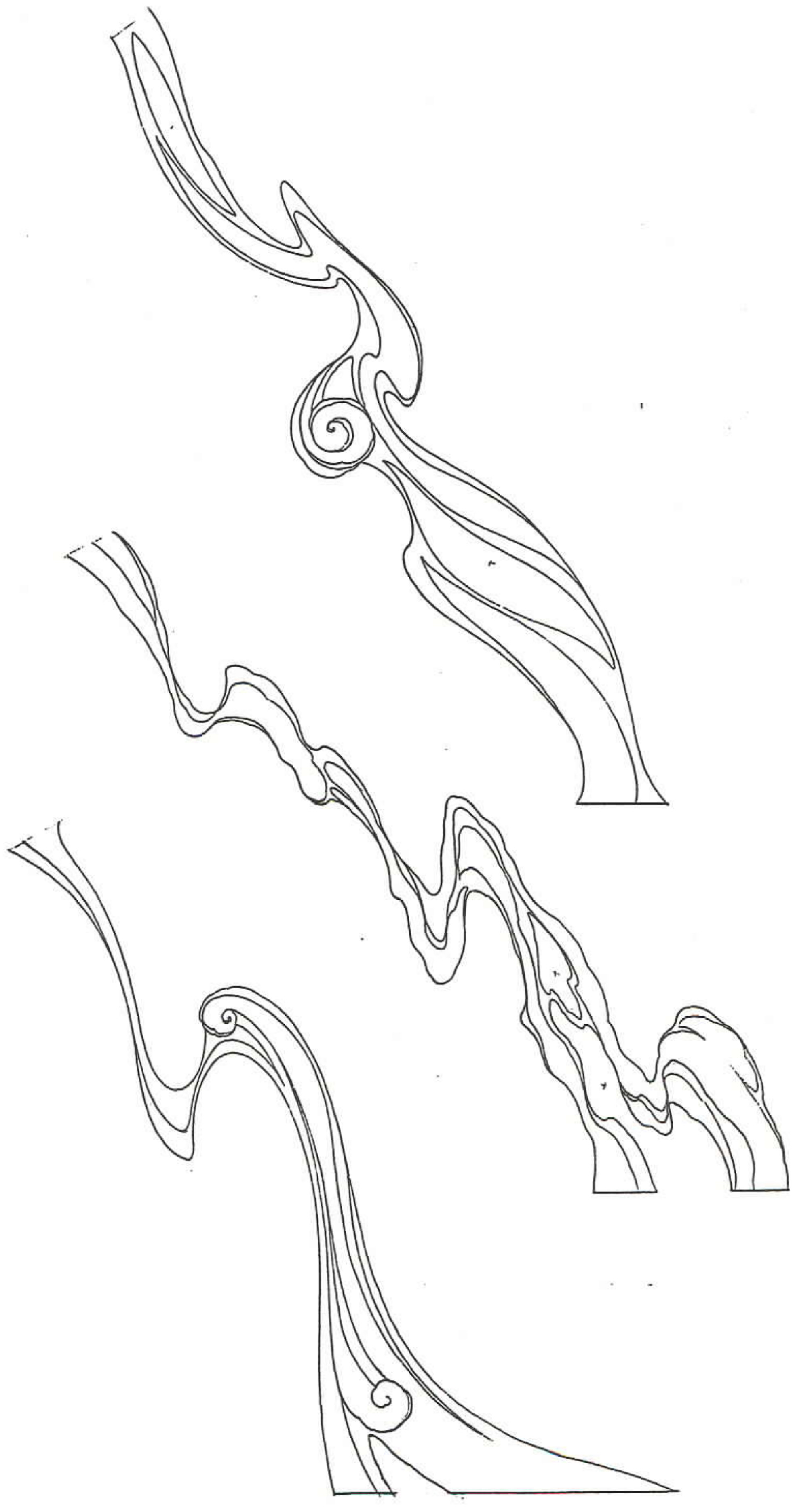


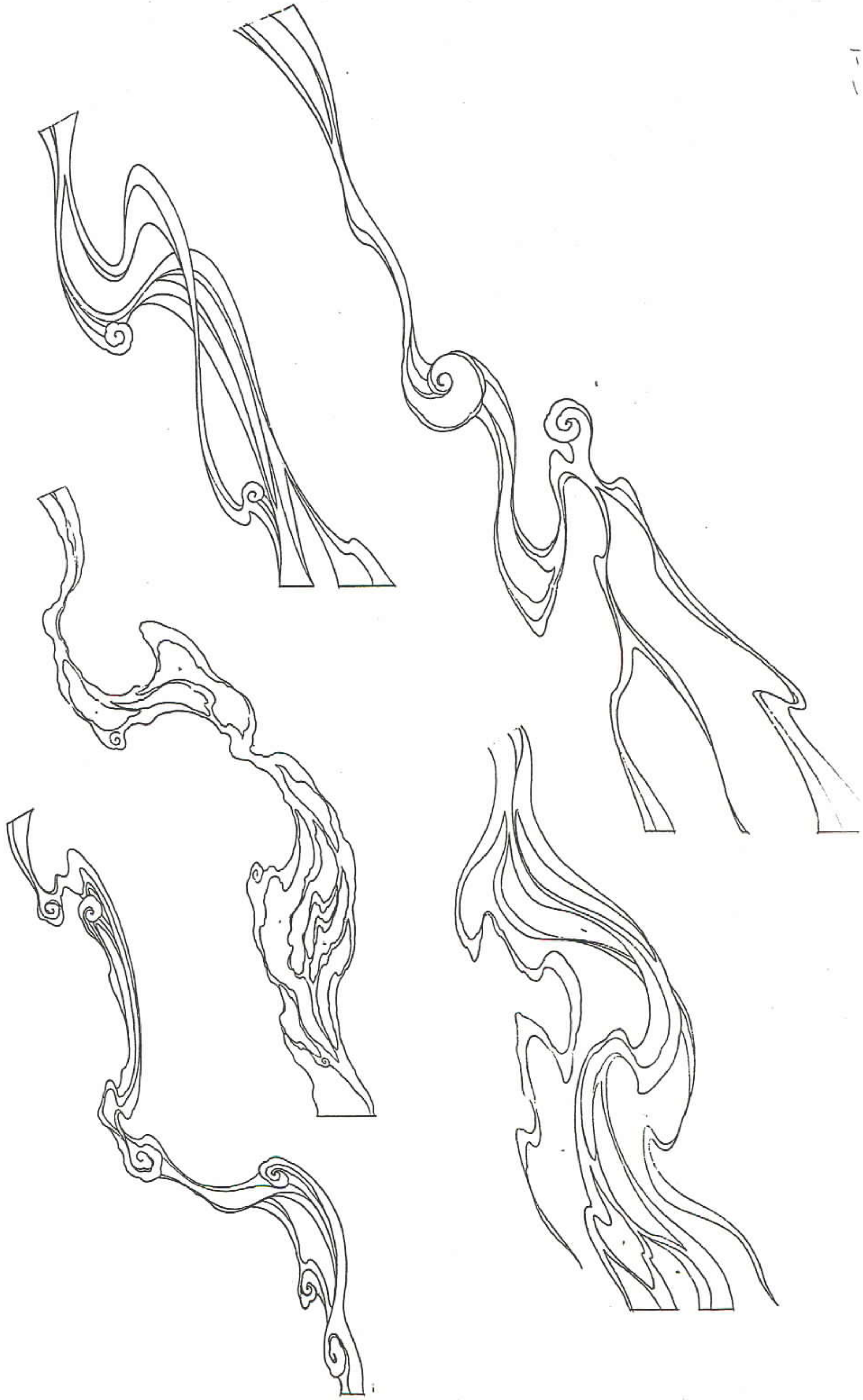
Garrett











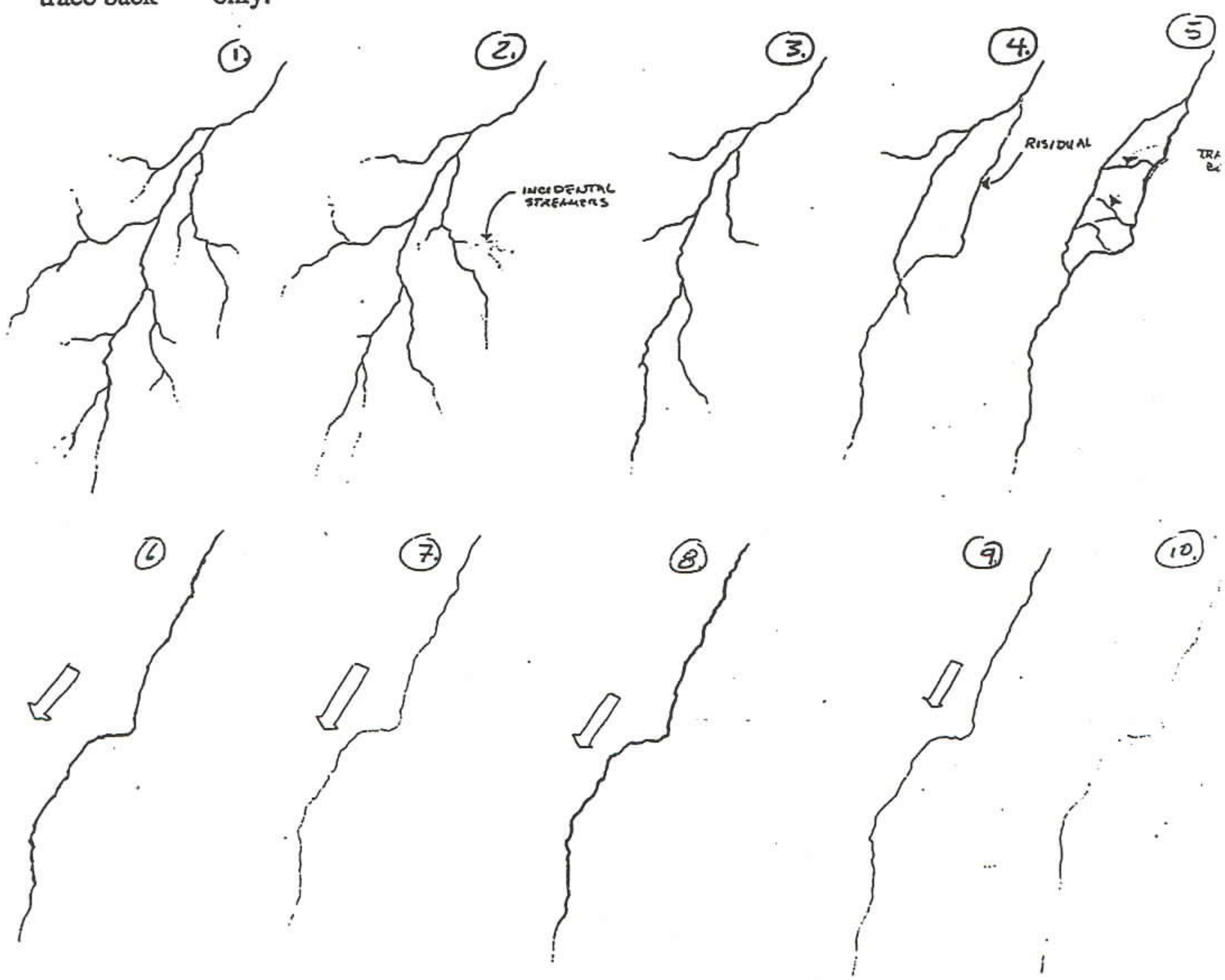
LIGHTING

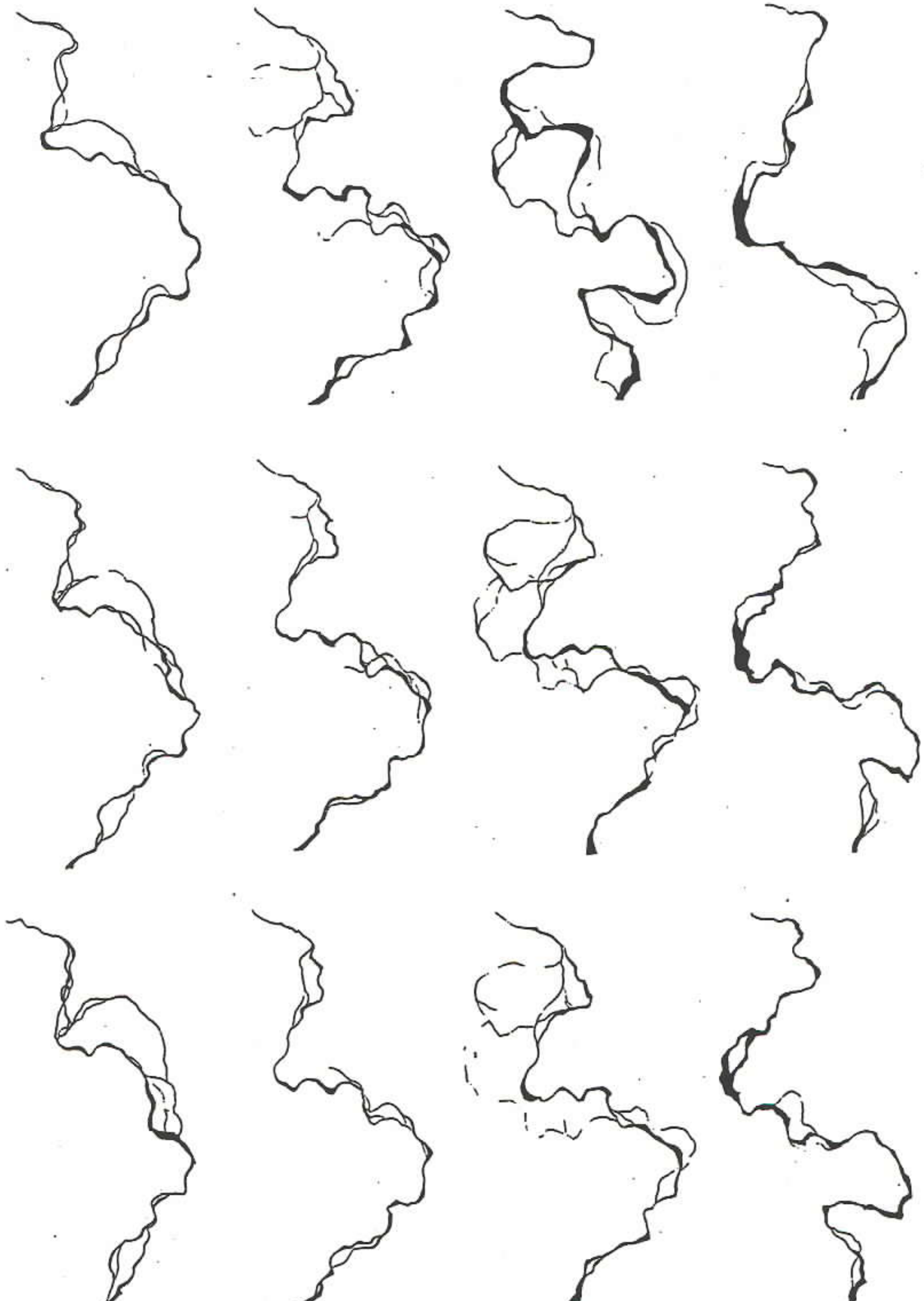
-First come up with a deign for what you want your lightning to look like.

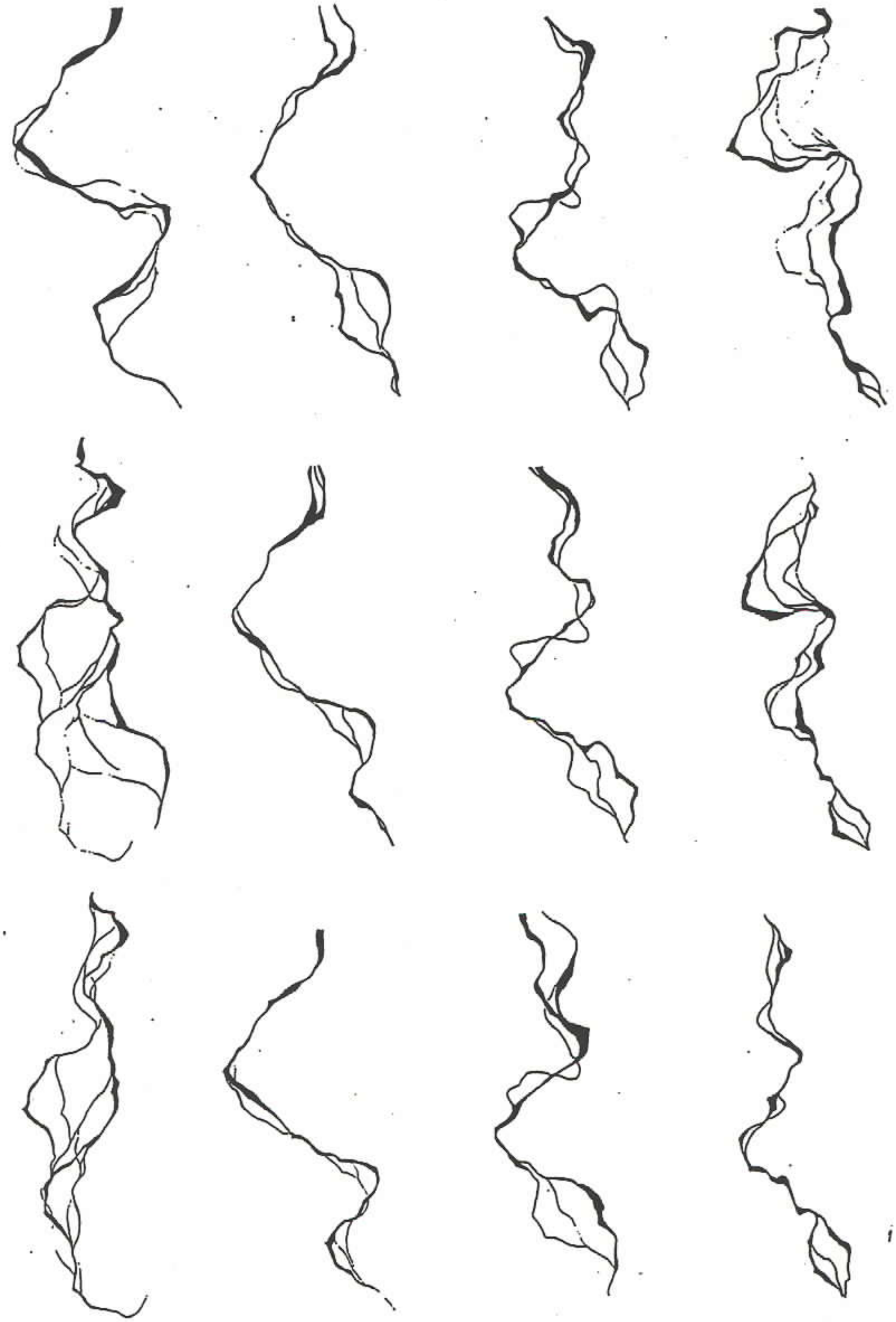
-Work backwards form that, illiminating parts of your design as you go. Keeping track of key areas of the bolt that you can use for directional movement.

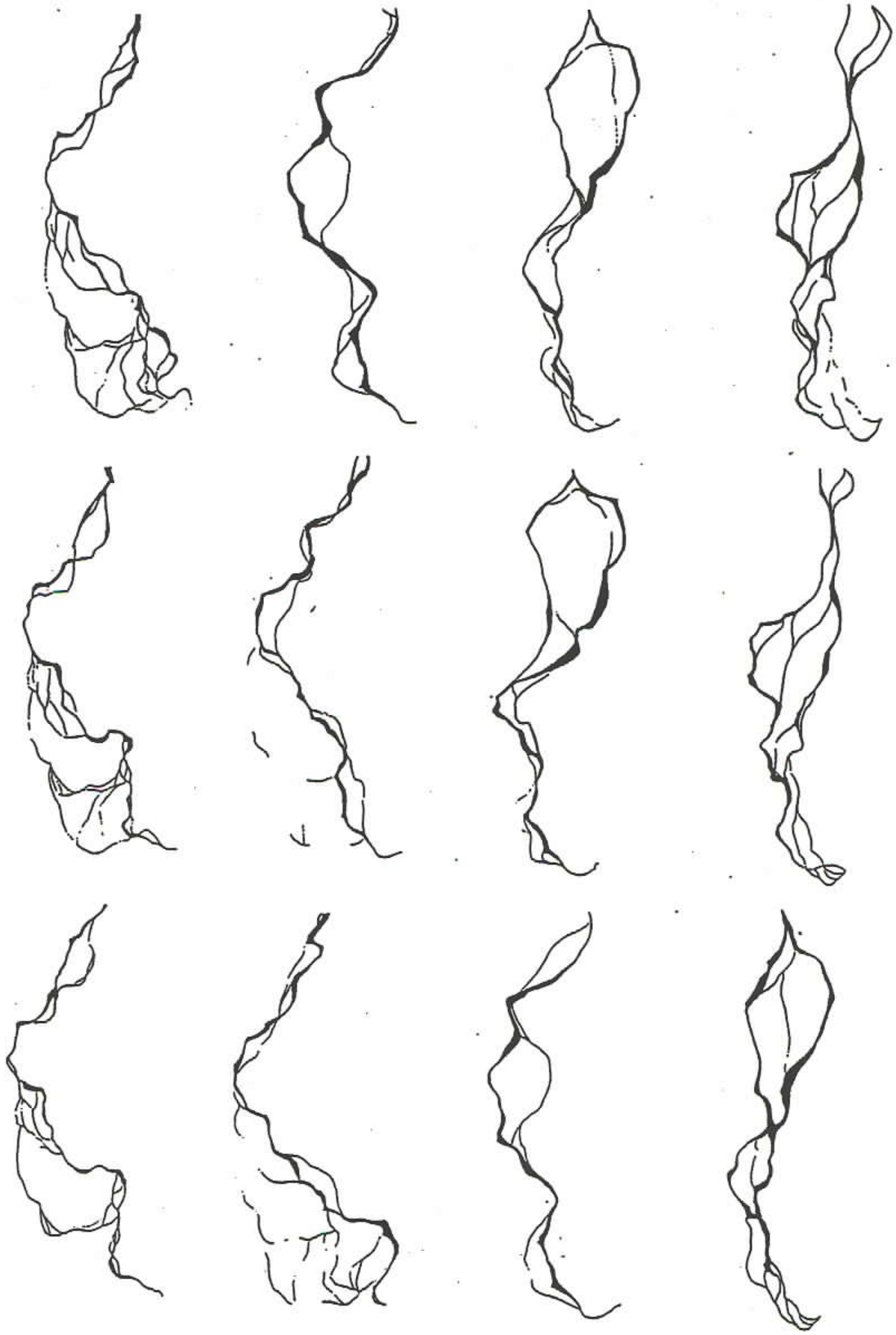
-Once you've established you main bolt action ~~you can~~ begin breaking down your animation. You may wish to have your main bolt "snap" into another position. Perhaps add some minor trailing bolts to act as speed lines. These would dissipate in 2/3 frames. Your previous main bolt would stay in its final position by just tracing it back with each succeeding drawing traced back thinner from any where from 3-4 frames to 12-16 frames. In other words Residual Images or Bolts.

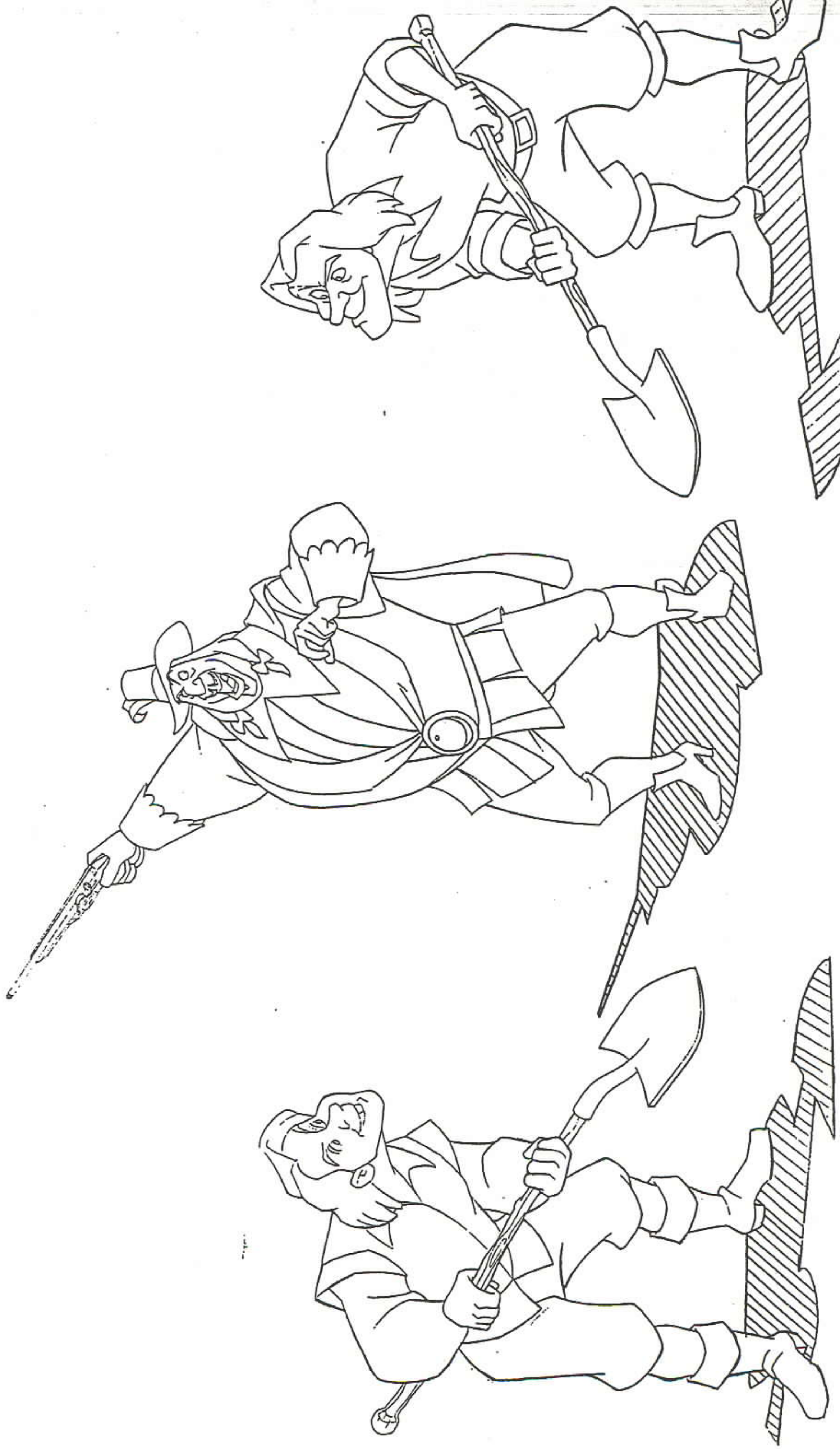
-Incidental fine streamers can be added and remain on screen for 2/4 frames. These could appear in their final and complete design instantaneously no animation is needed, trace back only.

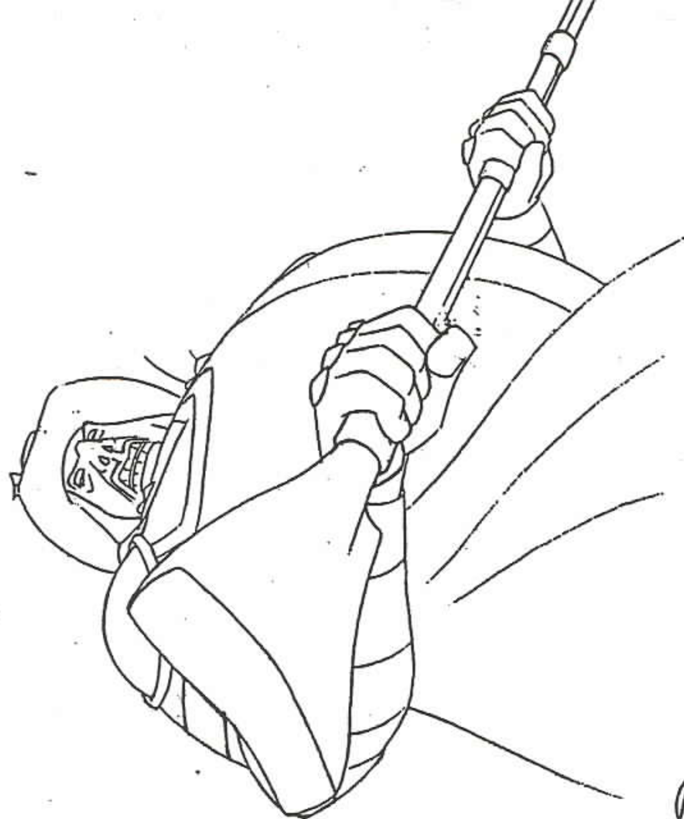


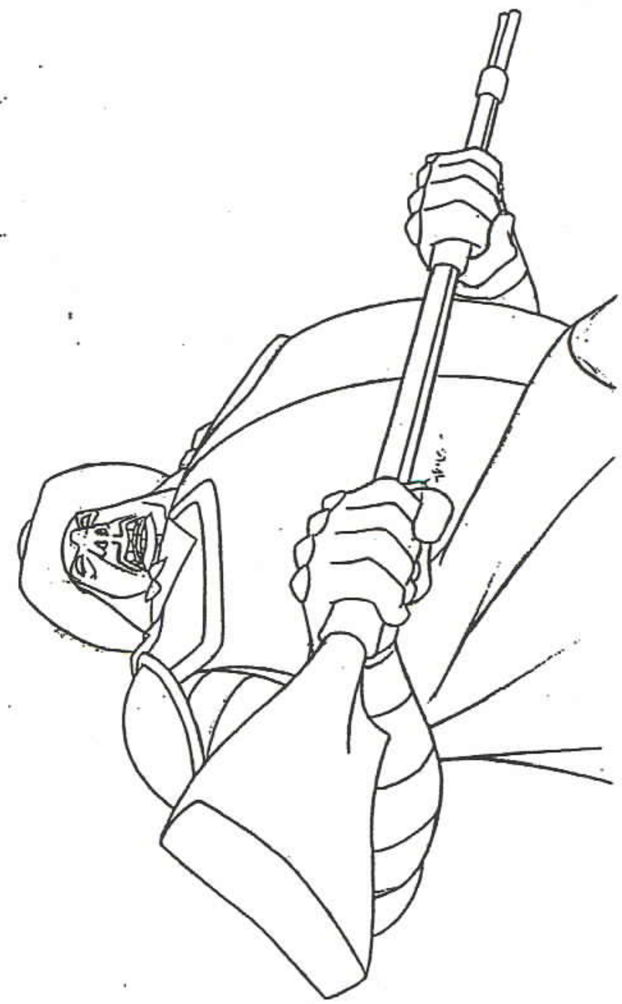


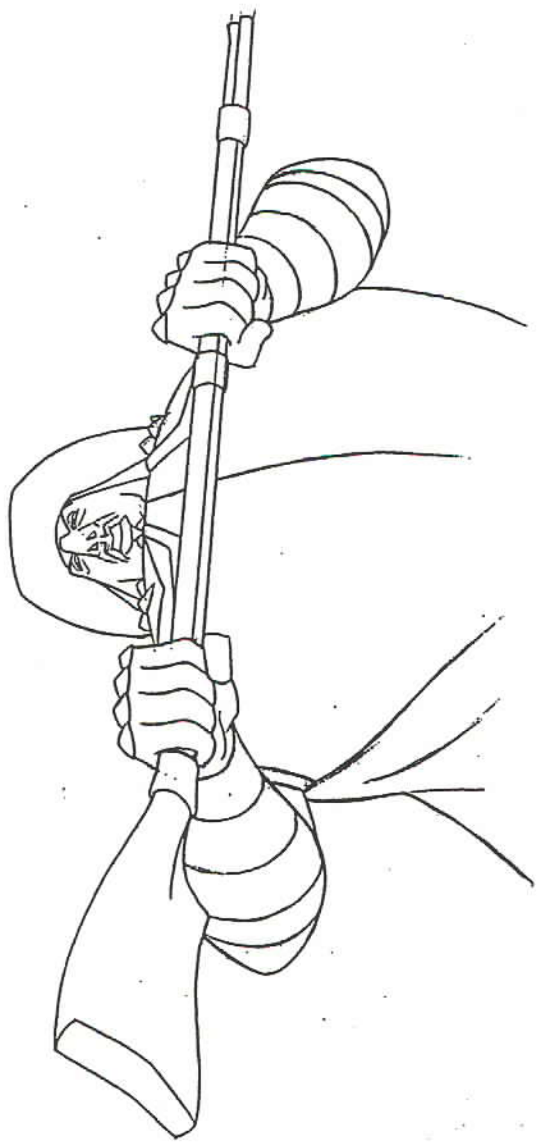


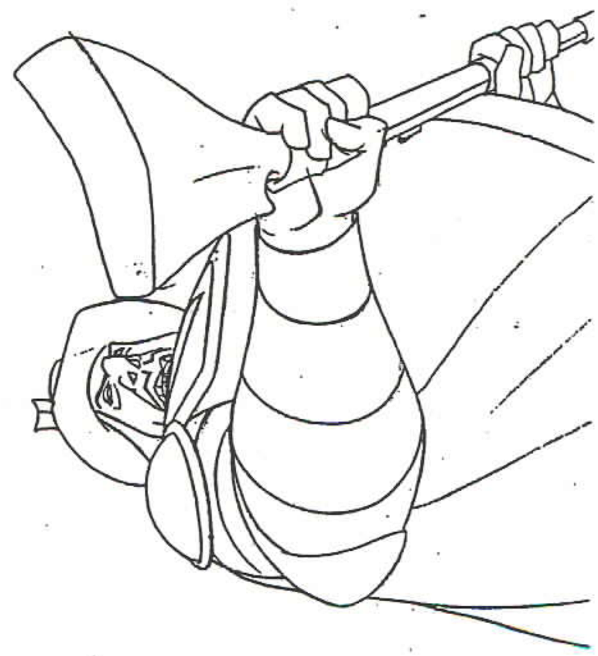


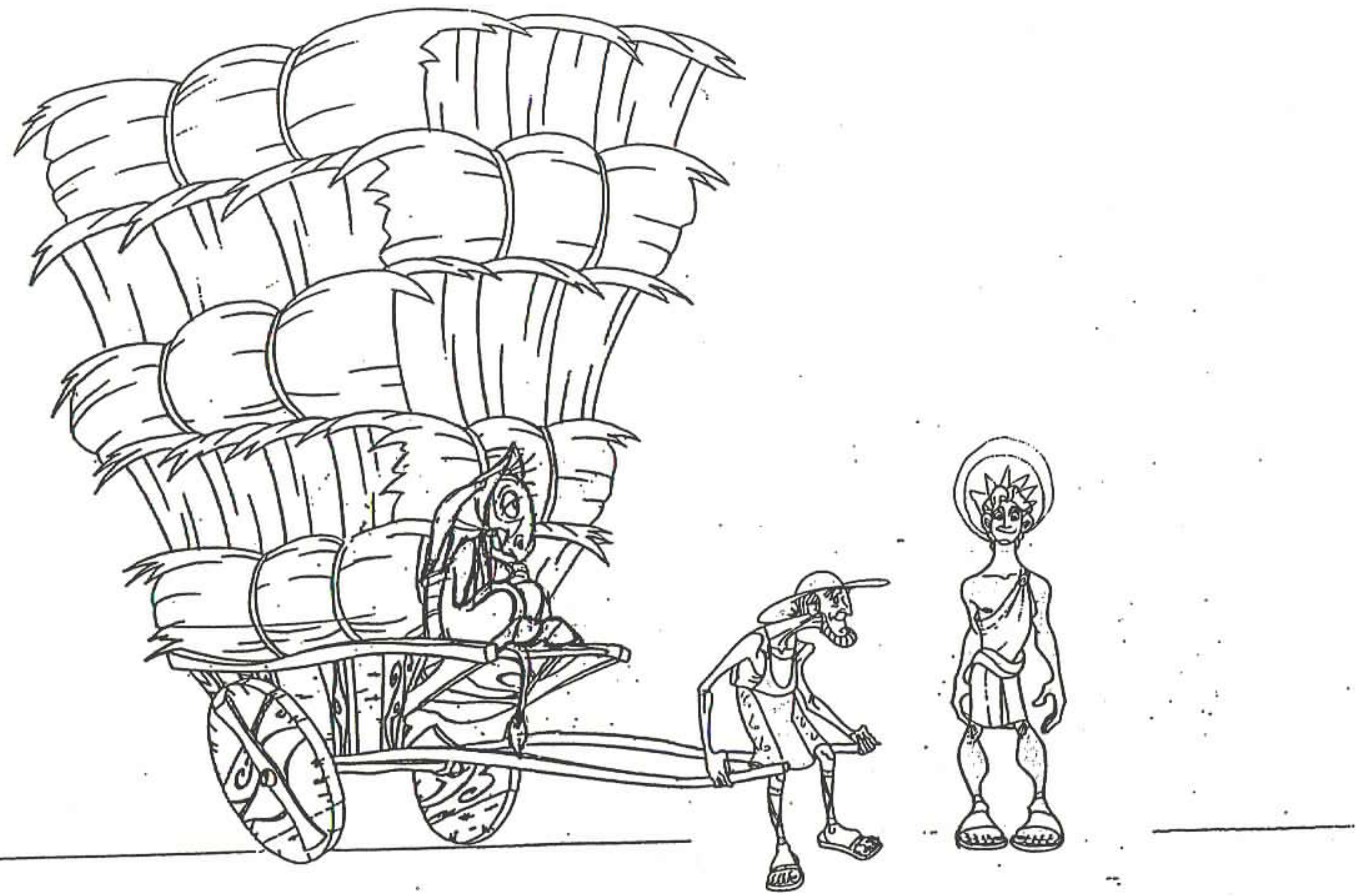












HERCULES

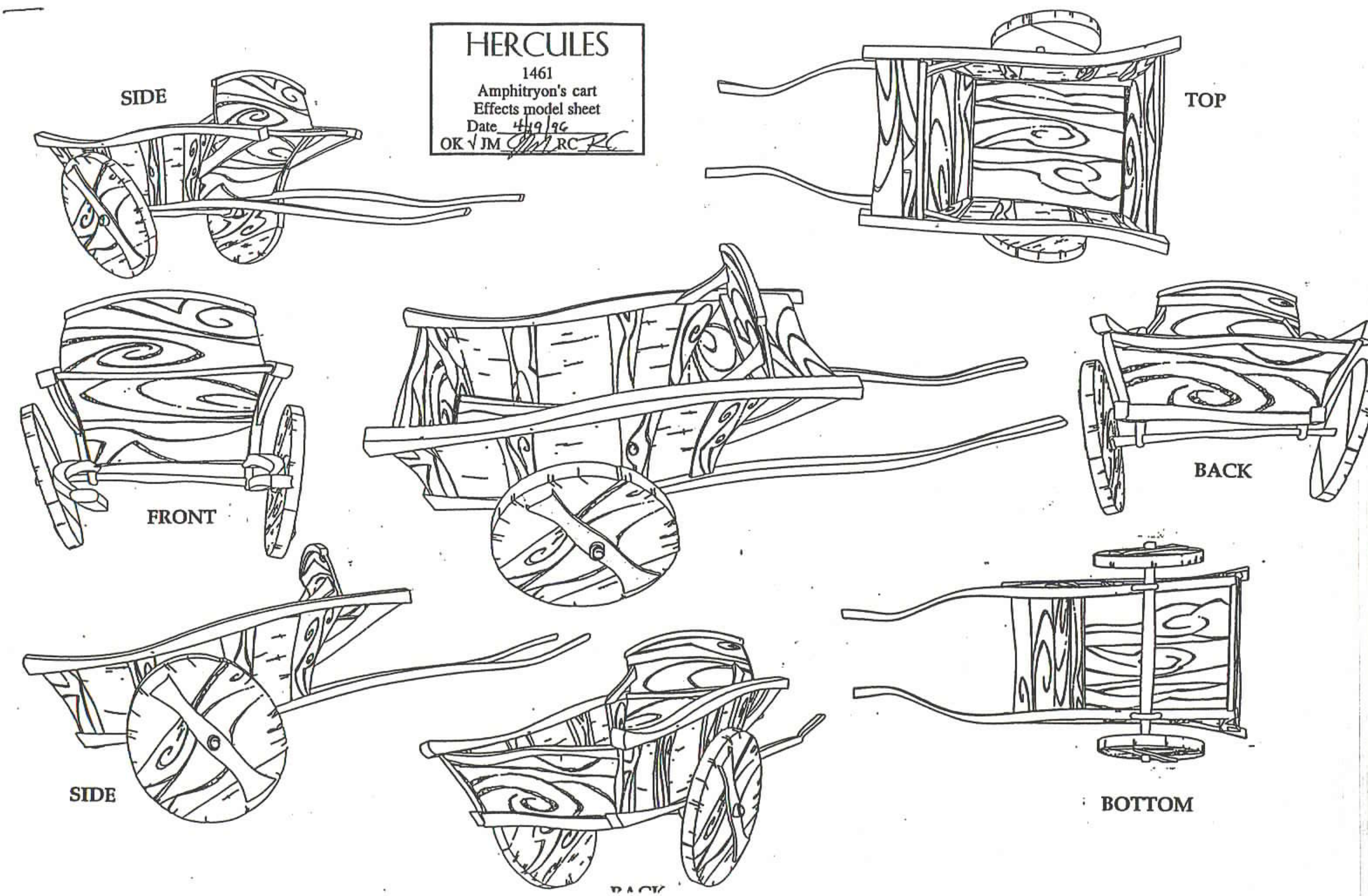
1461

Amphitryon's cart w/char.

Effects model sheet

Date 4/19/96

OK √ JM ____ RC ____

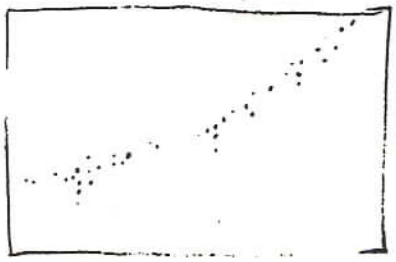

HERCULES
1461
Amphitryon's cart
Effects model sheet
Date 4/19/96
OK √ JM RC
SIDE
TOP
FRONT
BACK
SIDE
BOTTOM

BREAKING OBJECTS.

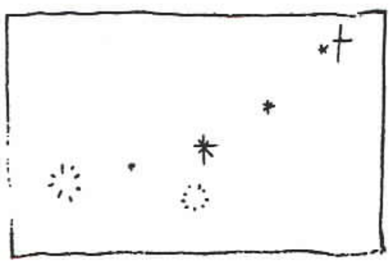
IN THIS EXAMPLE OF SMASHING ICE, YOU CAN SEE THE SOMEWHAT CRYSTALLINE STRUCTURE OF THE SHAPES. BREAK SHAPES UP WITH RANDOMNESS IN MIND. AVOID REPETITION AT ALL COSTS!

PIXIE-DUST DESIGN

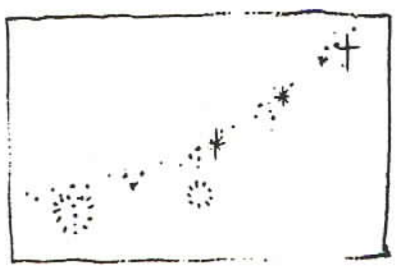
* ABOUT 90% OF A PIXIE-DUST DESIGN CAN BE SIMPLE DOTS, OR POINTS OF LIGHT, THE OTHER 10% CAN BE MADE UP OF ANIMATING STAR-LIKE SHAPES WHICH CAN TWINKLE AND PULSE, OR ROTATE, OR TUMBLE OR POP!



· SIMPLE POINTS OF LIGHT



ANIMATING STAR-SHAPES



COMBINE THE TWO.

* IT IS POSSIBLE IF DESIRED, TO CALL FOR YELLOW POINTS OF LIGHT, AND PERHAPS BRIGHT PURE-WHITE STAR-SHAPES. THE RESULT IS FULLER, WARM AND MORE 3 DIMENSIONAL LOOKING PIXIE-DUST.

* ANIMATING STAR SHAPES

THERE ARE 3 PRINCIPLE WAYS OF ANIMATING YOUR BASIC STAR SHAPE.

(1) TWINKLING

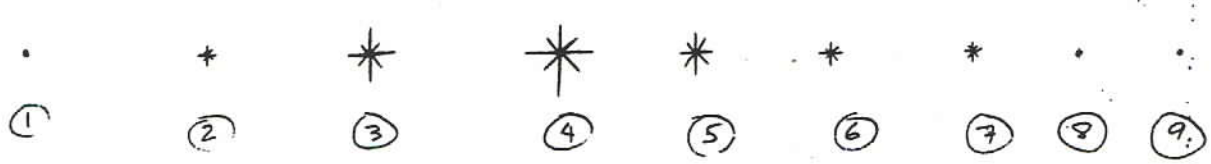
(2) TUMBLING

(3) POPPING

BY COMBINING THESE 3 BASIC TECHNIQUES, AND USING YOUR IMAGINATION TO CREATE NEW VARIATIONS, YOU HAVE QUITE A GRAB BAG OF PIXIE-DUST F.X. POSSIBILITIES.

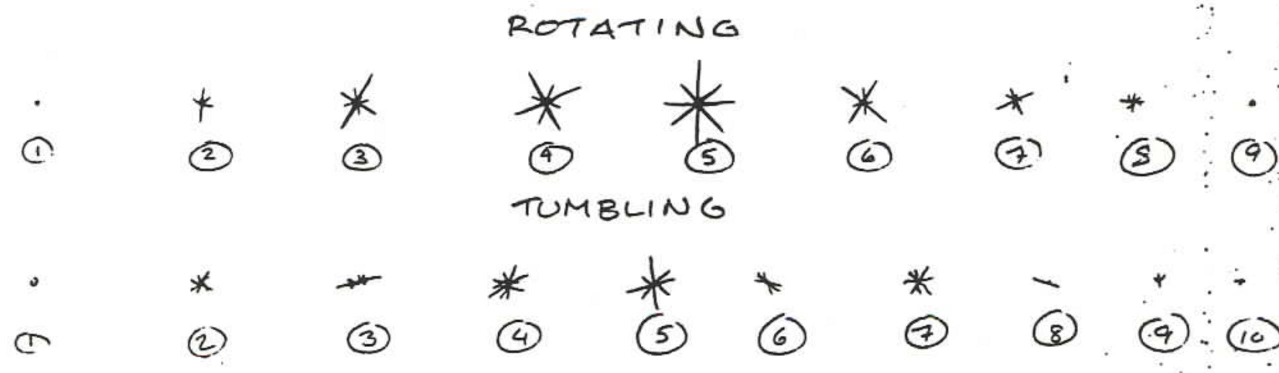
(1) TWINKLING

TO CREATE A TWINKLING EFFECT, A STAR CAN START AS A POINT, GROW IN SIZE AND THEN DIMINISH.



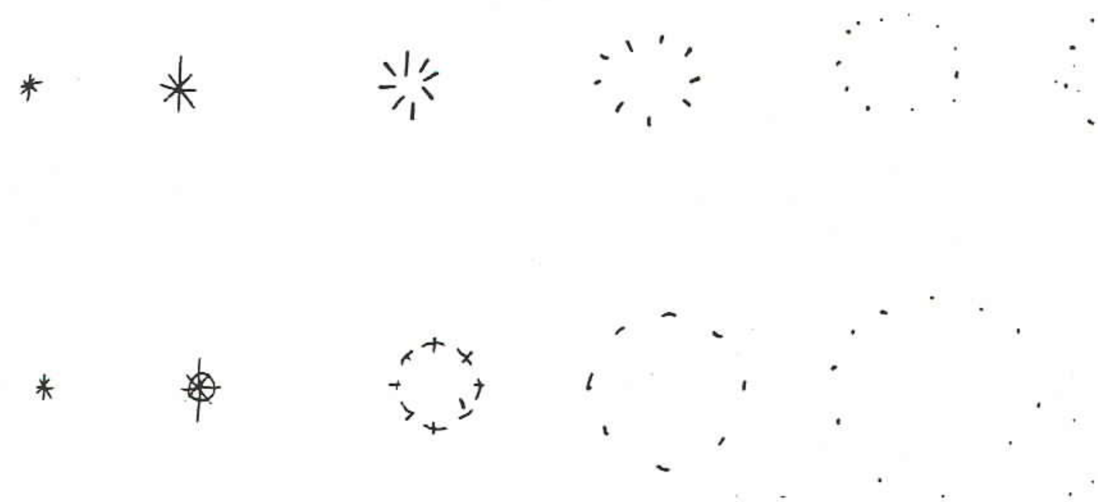
(2) TUMBLING

AS A STAR SHAPE GROWS AND DIMISHES IT CAN ROTATE ON IT'S CENTER AXIS OR TUMBLE LIKE A SNOW-FLAKE.



(3) POPPING

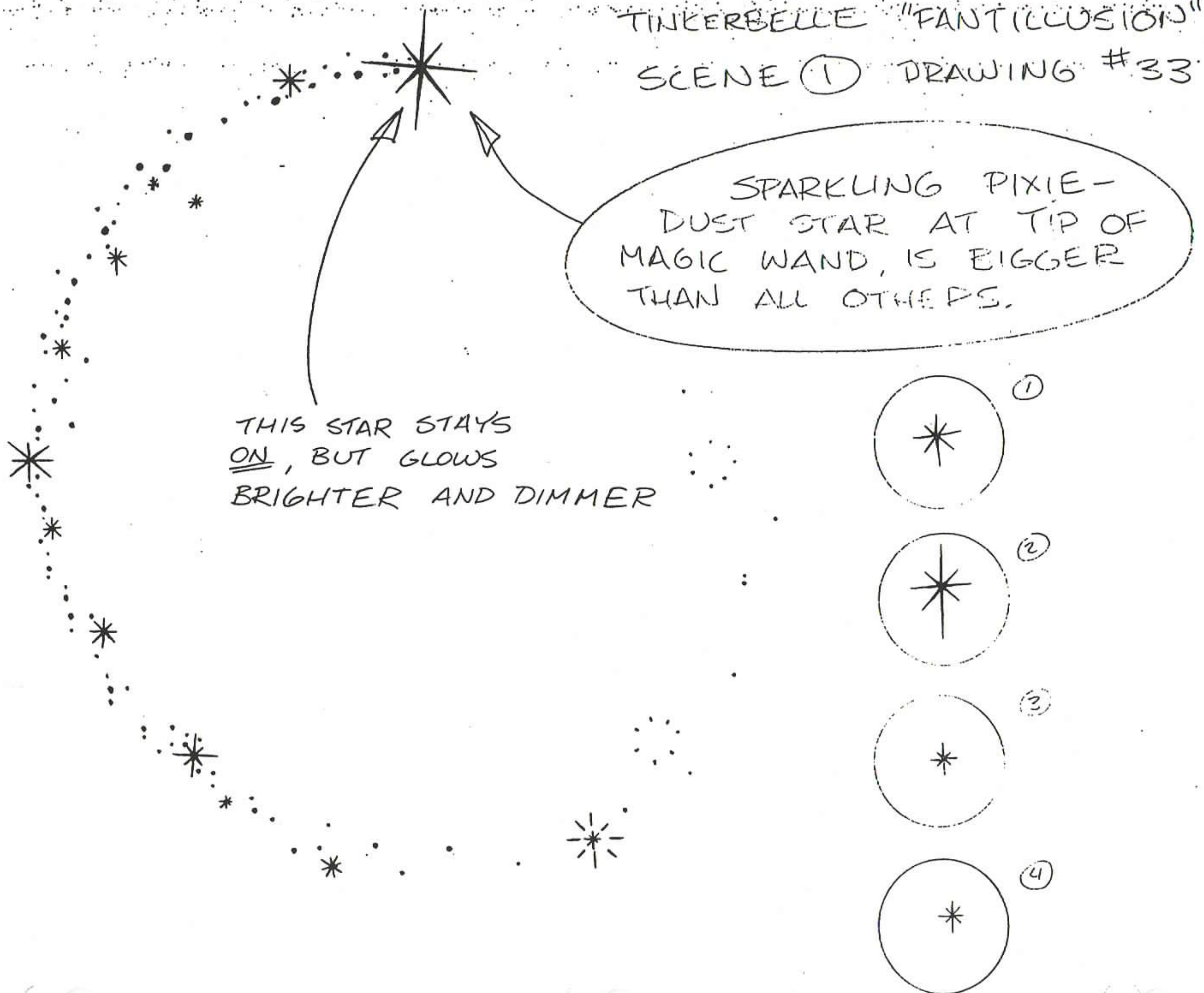
POPPING STAR SHAPES IS MUCH LIKE BURSTING A BUBBLE.



THESE POPS CAN LAST FOR 4 TO 12 FRAMES.

TINKERBELLE "FANTILLUSION"

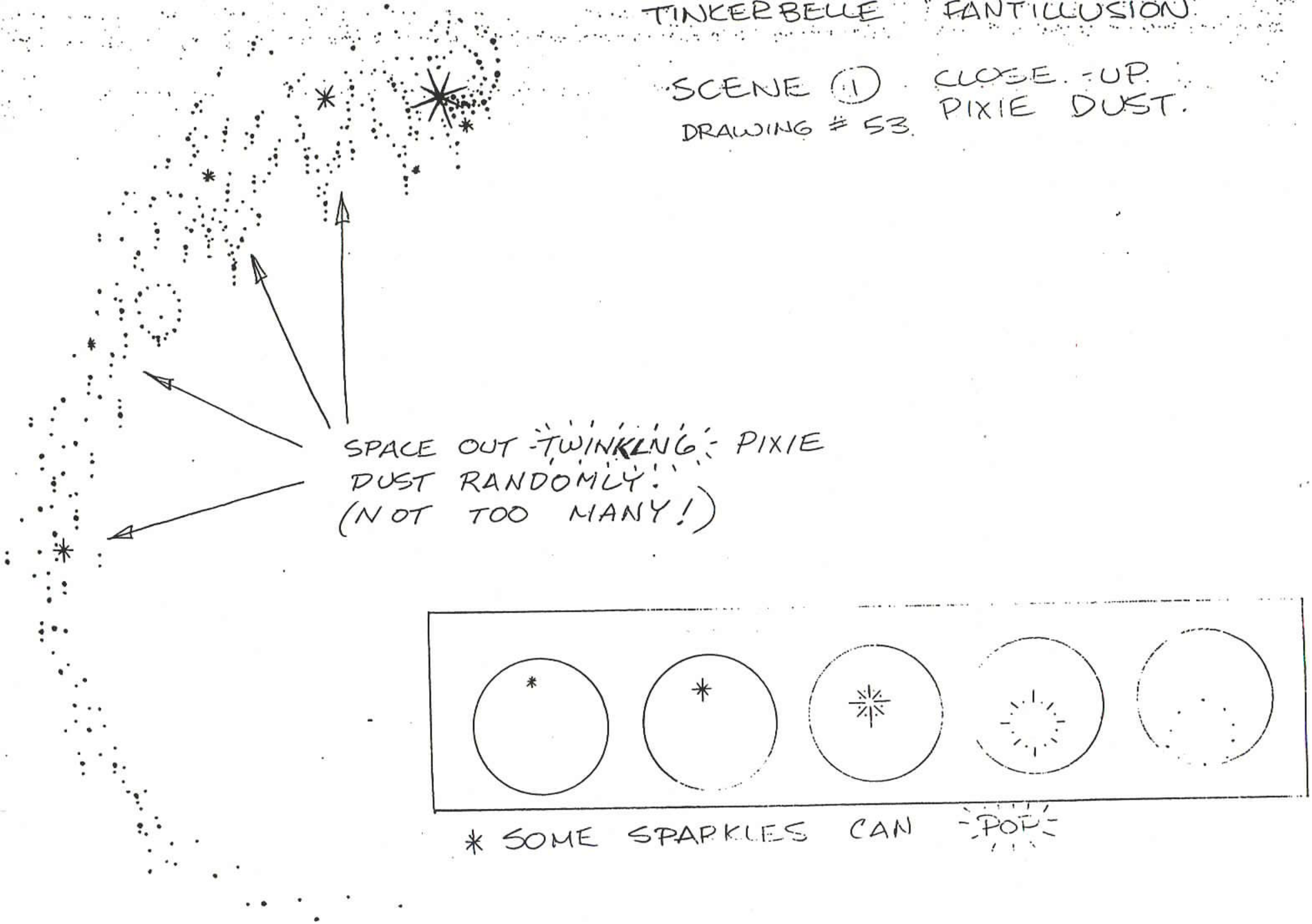
SCENE 1 DRAWING #33



TINKERBELLE "FANTILLUSION"

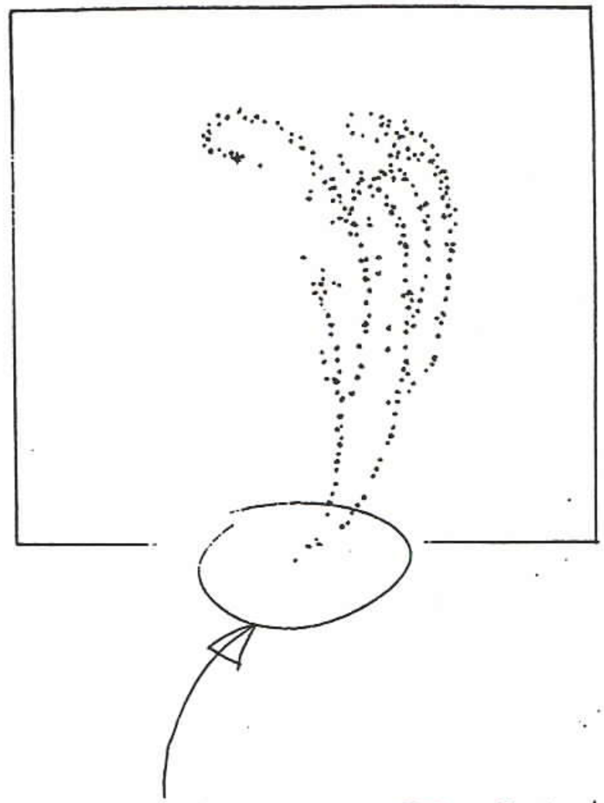
SCENE (1) CLOSE-UP PIXIE DUST.

DRAWING # 53

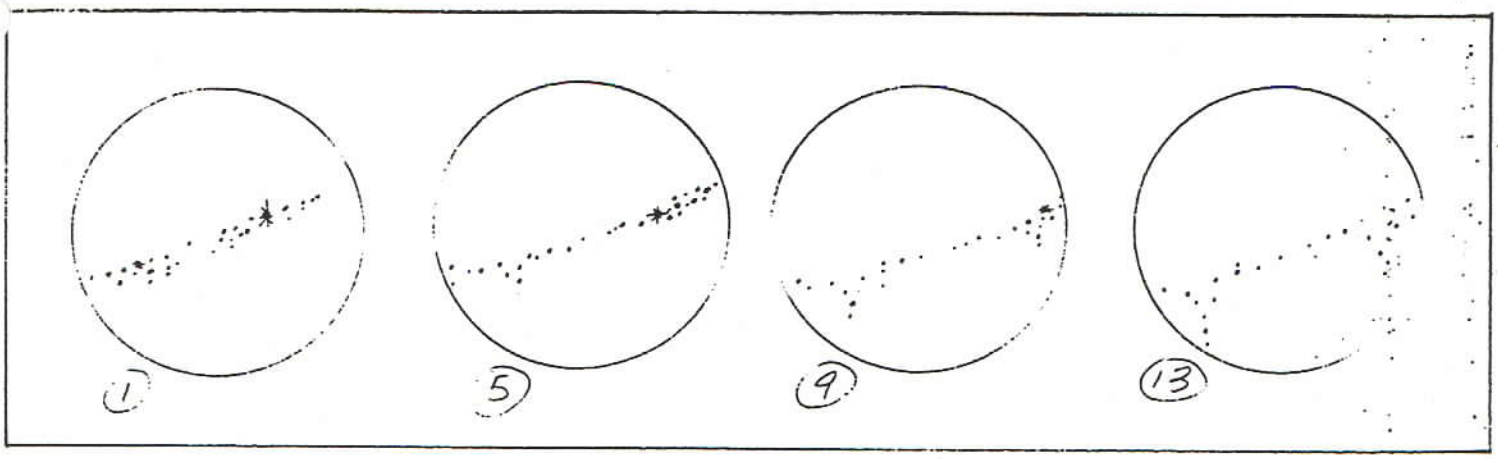


TINKERBELLE FANTILLUSION

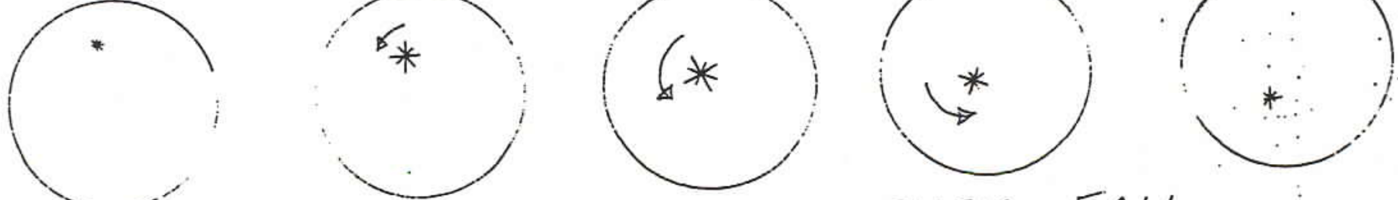
· BEGINNING OF SCENE (2) (DRAWING #17)



LAST DOTS TWINKLE OUT IN 3-5 DRAWINGS



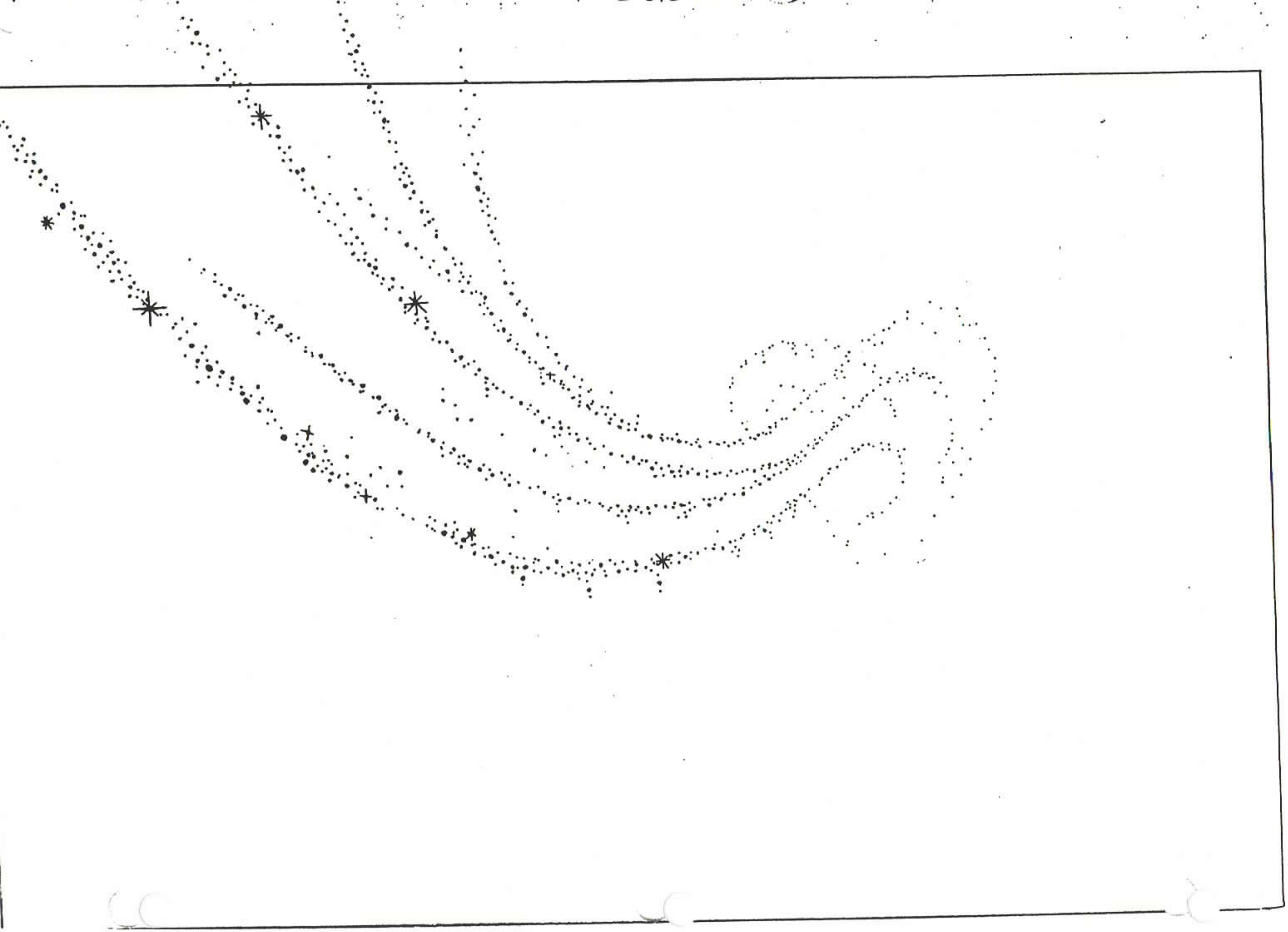
* THIS IS EVERY 2ND DRAWING.
LITTLE TWINKLES (*) ANIMATE ON + OFF EVERY 5 DRAWINGS (APPROXIMATELY)

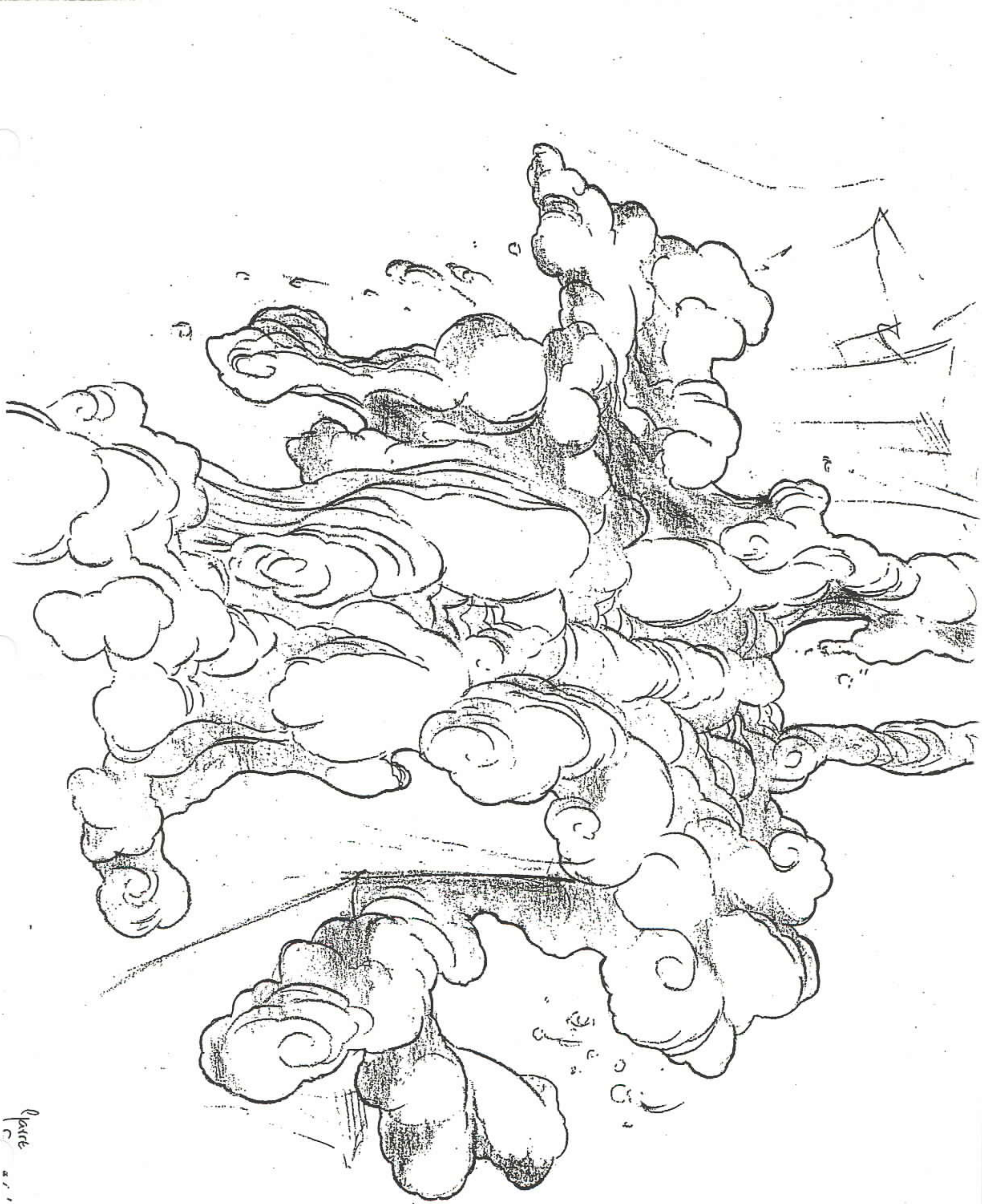


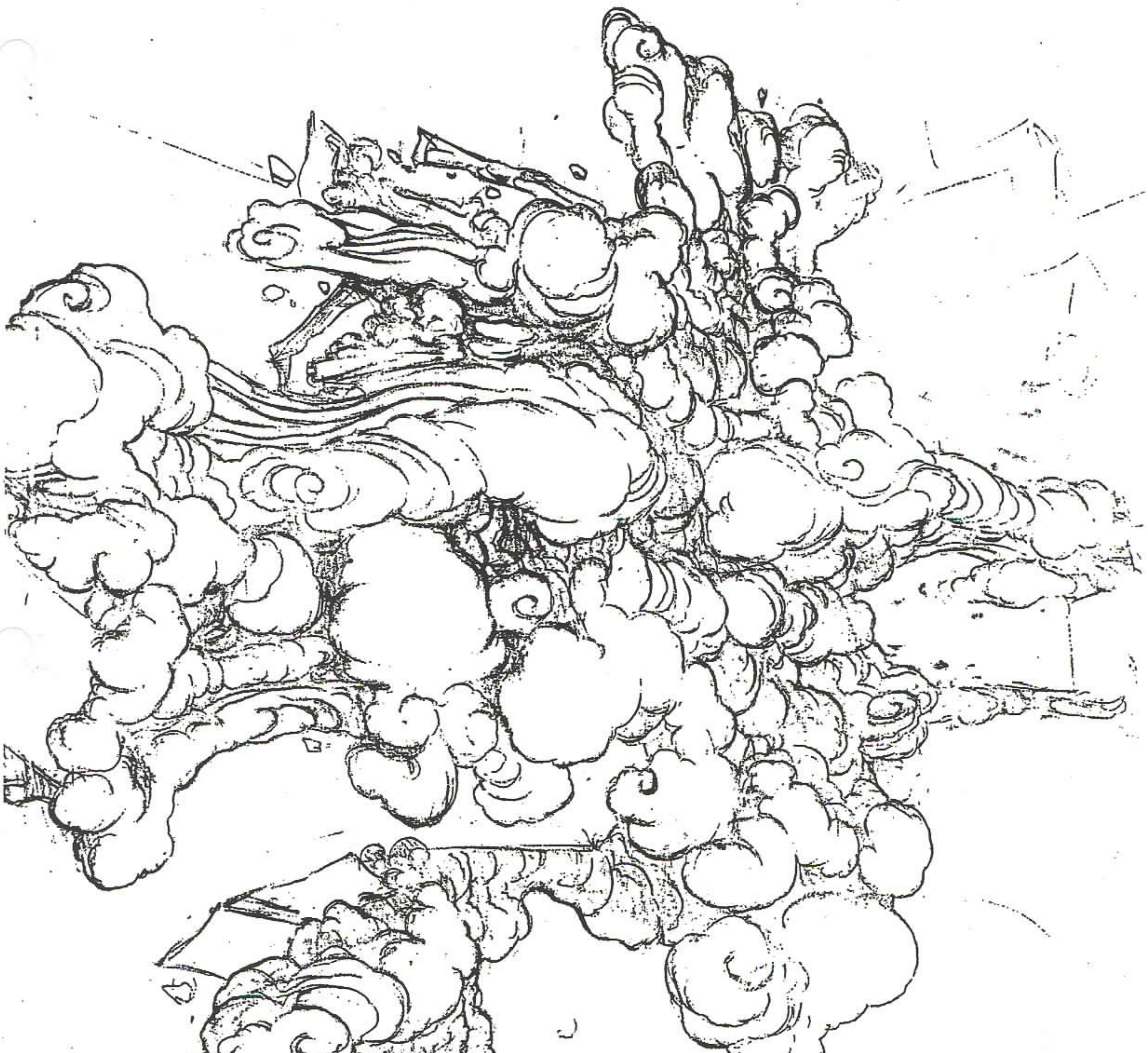
* TWINKLES CAN ROTATE AS THEY FALL

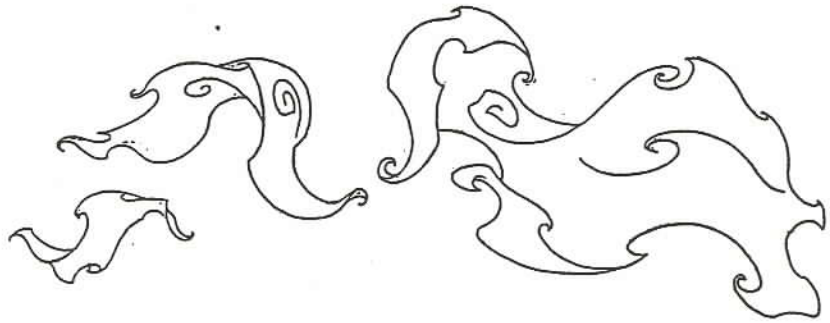
TINKERBELLE "FANTILLUSION"

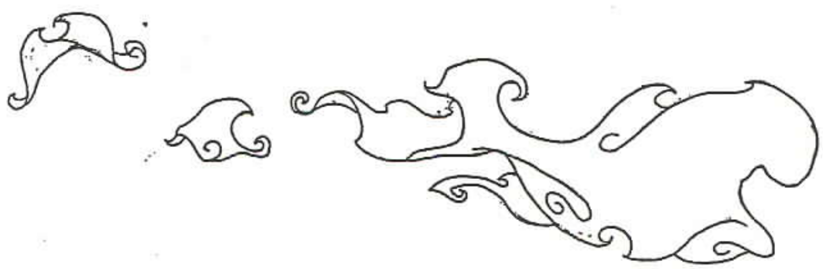
SCENE 2 DRAWING #30

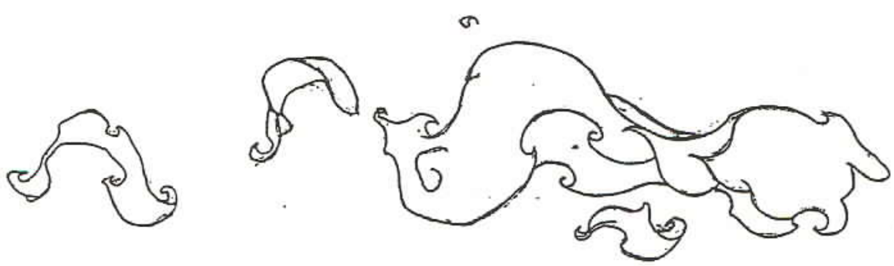


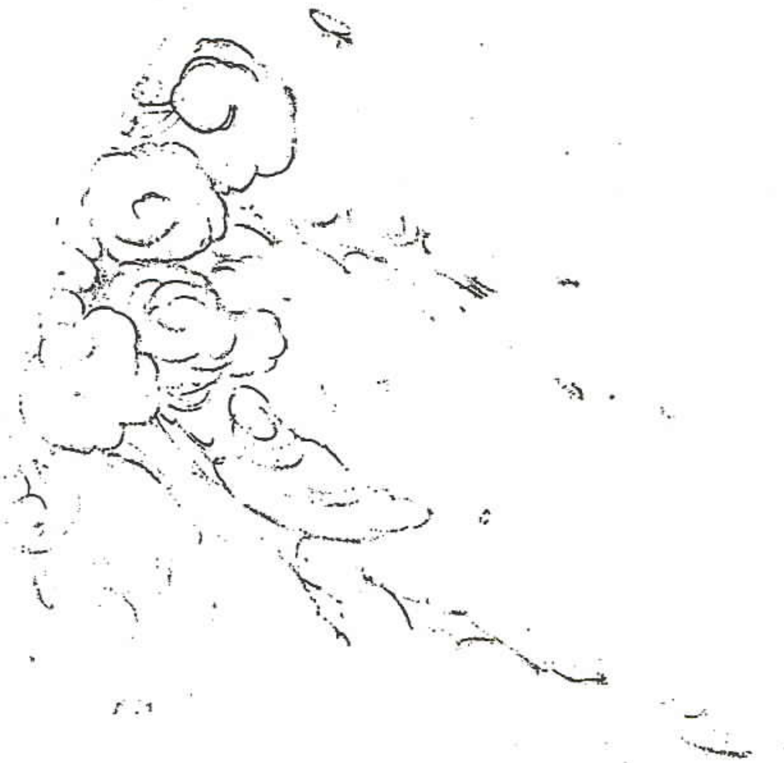


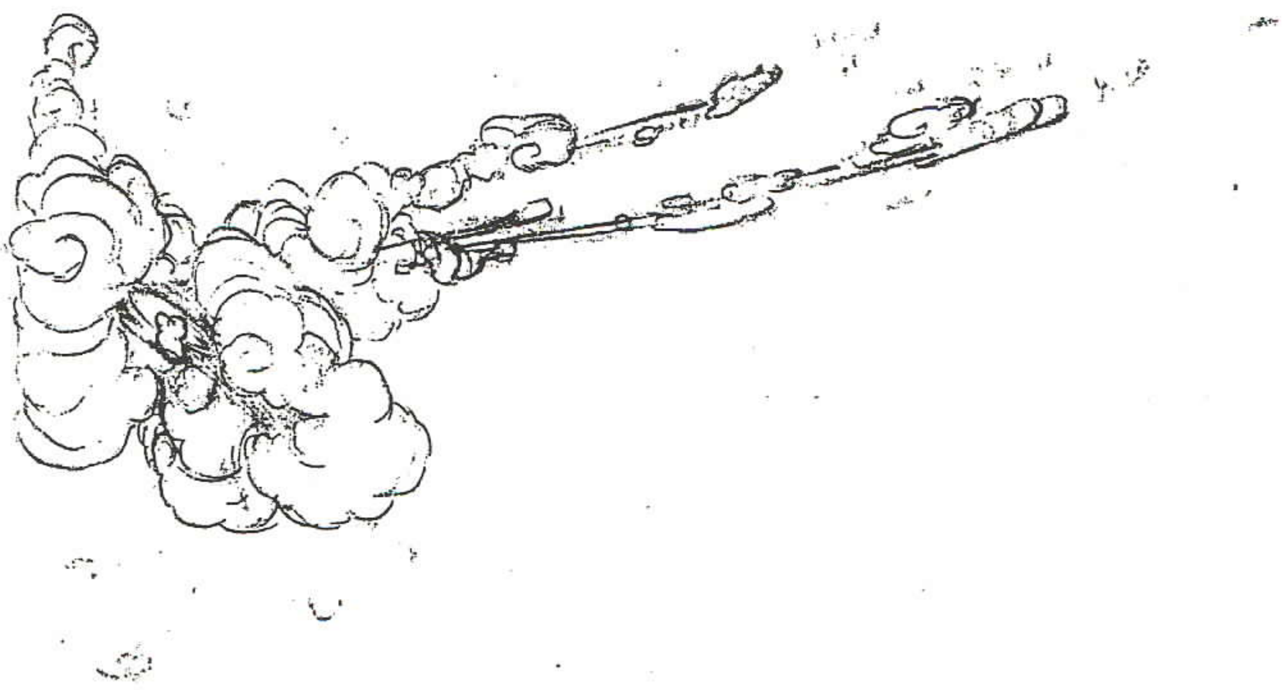










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Garrett
'Nov 95'